MUNICIPAL CHEMISTRY

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MUNICIPAL CHEMISTRY

A SERIES OF THIRTY LECTURES BY EXPERTS ON THE APPLICATION OF THE PRINCIPLES OF CHEMISTRY TO THE CITY, DELIVERED AT THE COLLEGE OF THE CITY OF NEW YORK, 1910

EDITED BY

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PREFACE.

A course of lectures entitled "Municipal Chemistry" was authorized by the Honorable Board of Trustees of the College of the City of New York for the spring semester, 1910. The lectures were open to the public, but laboratory work in addition was provided for senior students who elected the course. The co-operation of distinguished experts was obtained. Requests for copies of the individual lectures and the entire course have been so numerous that it was decided to put them in book form. In a few cases the lectures were not prepared for publication. These have been substituted by specially prepared articles.

A perusal of these chapters cannot fail to prove interesting to any citizen and the writer feels that their study will accomplish good in any community, for they tell of the applications of enlightened common sense where people congregate and form cities; but they will avail little more than attract passing attention unless any interest aroused is converted into kinetic civic activity.

A careful study of municipal affairs shows that the greatest material need of our American cities today is the chemist. It is unfortunately true that the position of the chemist in the municipal body politic is uncertain, if indeed it exists. This is due in a measure to the conception of the rôle of a chemist by the people, who look upon him as an analyst and not as an important social factor.

One of the objects of these lectures has been to correct this condition of affairs. It is believed by the writer, who has given the matter the most careful thought, that if each city in the United States, and in other countries as well, established a scientific commission of power, unhampered by political, social, religious or official associations, to advise with the authorities on all practical matters, the public weal would be improved in many ways and its affairs more wisely administered than by any

of the reform movements now in force which, by virtue of their organization, must be temporary.

Some aldermen may draw back from putting some of the ideas set forth into effect on the score of expense. That raises the question of their civic responsibility. It may not be worth while to spend money to save the lives of some people, but it is for others, especially the innocent. The successful manufacturer spends money willingly to improve the efficiency of his machinery. It is positive and not negative economy that counts most. Superior sanitary conditions affect human efficiency in the same way and those who are benfited are the better able to pay for it. Justified expenditures, even increased, for public work, in which the city's money has the same purchasing power as that of a private corporation, do not hazard an alderman's tenure of office.

It has not been possible in any case to present a complete discussion of any one of the topics taken up in the several chapters—technical details were unsuited to the plan of the lectures—and much given in the lectures has been eliminated in their publication to avoid an excessive number of pages in this volume.

My private assistant, Mr. W. A. Hamor, has followed the proof sheets.

CHARLES BASKERVILLE.

COLLEGE OF THE CITY OF NEW YORK, December, 1910.

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CHAPTER I.

Sanitation and the City.

CHARLES BASKERVILLE, Ph.D., F.C.S.,
Professor of Chemistry and Director of the Laboratory, College of the City of New York.

Living resolves itself into the moving of muscles and thinking. Essential to the performance of either is energy, the result of chemical changes. These are brought about in food, taken in its ordinary sense, which is the fuel; the air, which brings about its combustion, supplying the energy; and water, which serves as the common carrier of the food and the exhausted fuel. No violence is committed, therefore, in asserting that living is essentially chemical action.

Great cities have grown and passed out of existence. The enormous increase in urban population in very recent years has produced even greater cities, which may also in time cease to be. In fact, aside from the possibility of local or cosmic calamity, this is sure to occur, unless due attention is given to the application of the principles of chemistry in our daily, personal and communal life. London, Paris, Bombay, Rome and New Orleans have had their scourges in the past to testify to the fearful penalty of ignorance and neglect.

Indications point to a growth and development, the conception of which taxes the imagination. When we see New York as it was 200 years ago, and then 100 years ago, and as it is now, we may well wonder what it may be 50 years from now. In fact, New York City today, which may be taken as an example, has as many people within its 326 ¾ square miles as are distributed over the States of Maine, Vermont and Massachusetts combined, with their 47,070 square miles of territory, or as were within the

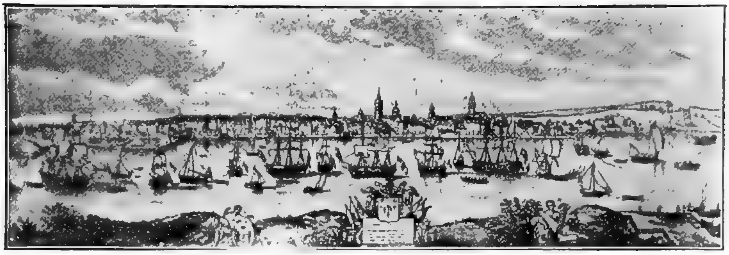

FIG. 1.—NEW YORK IN 1746.
(Courtesy of the *Scientific American.*)

FIG. 2.—NEW YORK AT THE BEGINNING OF THE NINETEENTH CENTURY.
(Courtesy of the *Scientific American.*)

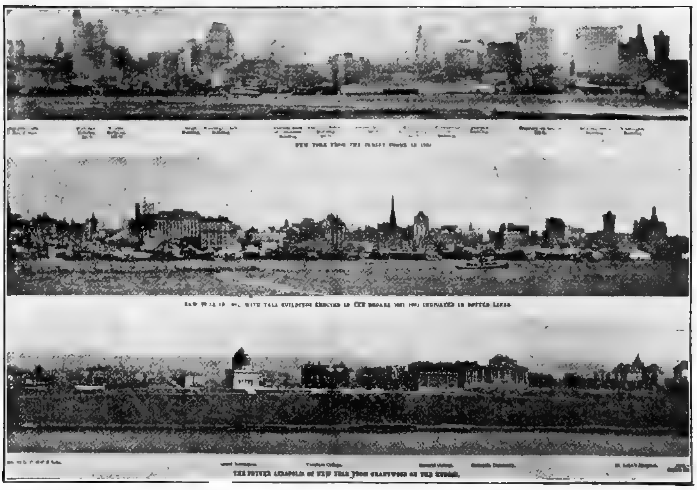

FIG. 3.—NEW YORK CITY VIEWS.
(Courtesy of the *Scientific American.*)

entire country at the end of the Revolutionary War. The annual increase in population is about 300,000. It has been calculated that in 1920, New York may have 7,000,000 of people.

It has been predicted by a close and conservative student of sociology that two generations may see the eastern part of our country mainly composed of contiguous cities. In 1790, 3.3 per cent. of the population of the United States was urban. It was 33.1 per cent. in 1900. The problems of the state and county become closely interwoven with those of the city. The city will no longer be merely an accumulation of human beings in a particular locality, with its local problems and influencing the state mainly in a financial way, but the city will have become the state.

The individual needs fresh air, pure water, good food, safe shelter, and should have a clean body and something beautiful to look at. When he associates himself into a city his needs are not lessened but emphasized. The growth of a city causes it to assume, willingly or no, corresponding obligations. The inhabitants must breathe, they must be fed and watered, its wastes must be got rid of, facilities for the safe coming and going of its people at all times must be provided, as well as protection from fire or other adventitious circumstances which concern the welfare of the citizens. The needs thus simply stated are to be met by obligations which become more and more complex with the increase in population.

The topography of a district in which urban population has massed itself will, in a measure, regulate the mode of growth. Although improved methods of rapid transportation have overcome the *necessity* of concentration, yet business and other causes continue to make for centralization, with consequent elevation in the value of land, whose acreage is increased only by vertical expansion. The complications thus arising call not only for "the employment of well-trained, tactful, honest, energtic, and fearless health officials," but also lay a responsibility upon all forms of educational activity to bring about a "better appreciation by the people at large of what is conducive and what a menace to public health," and individual safety.

The physical body comes into this world bearing within a spark of the divine fire, life. It sputters and all becomes dark; sustained, it lingers and continues to glow—perhaps through

the seven ages of man—when flickering, it dissolves into the mysterious eternity whence it came.

The watchmaker may fashion his steel, other metals and precious gems so that a delicate mechanism results. This supplied with the proper form of energy may continue its operations until it wears out. The enquiring youngster with a hammer may in a moment demolish this machine, or an inquisitive knife point shatter a spring, injure a wheel, dislocate a bearing, and its usefulness is at an end. So with the delicate organism of the living body. While it is scarcely the dream of optimistic sanitarians, not even the desire, ever to have the body live on forever, there is not an unreasonable hope that we may arrive at that stage when the end of our lives may come from sheer old age, and like the "One-Hoss Shay,"

> " . it went to pieces all at once—
> All at once, and nothing first—
> Just as bubbles do when they burst."

It is extremely rare in our experience that a man dies of old age. The Reaper clogs a wheel of the human mechanism here, dams the channel of one of life's flowing streams there, brutally annihilating, with coarseness perhaps, or ruthlessly, slowly, surely smothering elsewhere. Thus death comes as a rule, not as a wearing out of the whole mechanism, as would be proper, but through the failure of this or that little function, and *that is disease.*

"Are we, the People of the United States, held in the bondage of disease? One out of every seven of us dies of tuberculosis; fifty thousand of us perish annually of typhoid fever, and ten times this number lie stricken for weeks each year with this disease, but ultimately recover. Pneumonia disputes with tuberculosis the right to be called the captain of death. Some 50,000 of us die annually of cancer and other malignant growths. More than 25 per cent. of our children die before they reach five years of age." (Vaughan.) Statistics show that the principal causes of death are disease, violence and old age in the respectively approximate percentages of 90, 5 and 5.

To be sure, the analogy of the living body as a wonderful mechanism fails if pushed too far, like all analogies, for the animal body may grow to maturity and be followed by normal de-

cline. Yet the analogy answers our purposes, as we also know that the human body may be well built or loosely put together, of good or poor material; that it is extremely sensitive to its environment; that it is a transformer of energy, but of variable efficiency. As in the case of the physical machine, we desire the highest efficiency through the longest period of time. Therefore, we are not alone concerned with the actual scrapping of the human machine, but quite as much with its efficiency while in commission.

FIG. 4.—COURTESY OF THE COMMITTEE ON THE PREVENTION OF TUBERCULOSIS IN NEW YORK CITY.

Sanitary Science, "*preventive medicine,*" the prevention of the ravages of disease, is a technical subject of modern development—"a subject so vast and touching human welfare at so many points"—which makes exacting demands for its complete mastery. Yet the principles involved lend themselves readily and happily to clear and popular exposition. The most active expositors of the science, which has recently received munificent financial support in many of the civilized countries, are the physicians themselves. While their lives are consecrated to the prevention of that which gives them a livelihood, I have never found one of them opposed to members of other professions participating in the making known of means for the prevention of disease. In fact, at times, there has been an exhibition of impatience with the laity for indifference toward matters of public health. I have found them objecting—and with good reason—to the practice of the art of healing by the unprepared and unqualified. They have objected also most strenuously, as did Mendenhall, who said: "It is not the popularization of

science that is objectionable, it is the popularization of what is not science that is obnoxious." In this connection, I am reminded of a saying of Lord Derby's, namely, "Sanitary instruction is even more important than sanitary legislation."

The curricula of the schools, colleges and universities, private and public, offer courses in sanitation at present. In many of these the successful pursuit of one or more of these courses is part of the requirements for advanced standing. It should be so in every institution of learning. The reputable public press seems ever ready to disseminate information about the subject. What has been accomplished is encouraging; what is being done now is stimulating; what remains to be done is engrossing, for we must not stop until every citizen realizes that the public health is the greatest asset of a nation.

Disease, considered as the cause of death, or as a hindrance to economical energy output, may be attributed to causes which are

(a) *Intrinsic* or *Constitutional,* and
(b) *Extrinsic* or *Environmental.*

In short, although the classification is not exclusive and is open to valid objections, and is a subject for fine academic discrimination, it may be said that the physiologist has to do with the intrinsic or organic defects, while the sanitarian gives his attention to the external influences which may or may not produce the former. The prevention of constitutional diseases, which is a special function of personal hygiene that involves certain social and sexual questions which find no place in our discussions, has to do with the making over of the human mechanism, a phase of social medicine, as it were, which usually involves the application of biologic principles through several generations. Environmental, mainly preventable, diseases are in a measure under our immediate control, and the exertion of our authority in this direction shows a conscious or unconscious application of the principles of sanitation. Perhaps this may be made clearer by illustration. The subject of proper food and clothing for particular conditions is a matter of general or personal hygiene; but the question of infection from clothing made in sweatshops, the disposition of second-hand clothing, whereby

the disease germs of small-pox or diphtheria are transplanted, belong distinctly to the field of sanitary science.

The sanitarian, in order to combat disease most successfully, or, to put it affirmatively, in order to promote the public health most effectively, should "be familiar with the causes of disease and the avenues along which they travel."

One of the earliest theories of disease coming to us from the days of savagery attributed fevers, pains, etc., to the presence of evil spirits, which made short or long visits to the affected individual. Although the New Testament bears record of this *demonic theory* of disease and although we know that this mystic cause obtains at the present time among certain classes of illiterates within our own enlightened country, it ceased to satisfy the cultivated mind even before the period of the highest development of Greek civilization. Hippocrates (460 B. C.), the "father of medicine," recognized disease, along with life, as a process governed by what we term natural laws and the healing power of nature. Galen's exposition of the theory showed that the "body contains *four humors*—blood, phlegm, yellow bile and black bile—a right proportion and admixture of which constitutes health; improper proportion and irregular distribution, disease." The field of thought was transferred from the supernatural to the natural.

The decline of Greek culture, the rise and fall of Alexandrian influence, the whole Roman period, even the benign influence of the Christ and its moral uplift, added little to the knowledge of the causation of disease. In fact, for two thousand years, through the period of scholasticism, the theory of the four humors held sway. The glorious time of the Renaissance emphasized it, for the revival of learning, even in the hands of "medical humanists," laid great stress on respect for ancient authority.

The iatro-chemist Paracelsus (1480-1541), the "Luther of Medicine," however, boldly assailed the doctrine. The outward evidences of his antagonism were perhaps in accord with the spirit of the age, for he gathered the writings of Hippocrates, Galen, and others of that school, and publicly burned them, maintaining that life processes and changes in the body could be accounted for on chemical grounds. Medicine was, in a measure, a branch of applied chemistry, and by some was looked upon

as the true end of chemistry. The occurrence in Europe in the 15th and 16th centuries of several epidemics, which were inexplicable on the theory of the four humors, the study of anatomy by Vesalius, Fallopius, and others in Italy in the 16th century, and the wonderful discovery of the circulation of the blood by Harvey in the 17th century, led to the recognition of a *materies morbi*—and the real foundation of the modern theory of the cause of disease was laid, whatever was to become the later conception of this *materies morbi.*

Sydenham (1644-1689), the English Hippocrates, maintained that "a disease is nothing more than an effort of nature to restore the health of the patient by the elimination of the morbific matter." It was felt that the "reign of canonical authority in medicine was at an end, though the dogmatic spirit long survived," and we see it around us today, three centuries later, in the preachment and practices of several cults.

This conflict we find in the 18th century, when Boerhaave became the successor of Hippocrates and Sydenham, leading the "naturalist" or material school. Their physical or mechanical conceptions of the causes of constitutional disease, however, did not explain that class of diseases now called "infections." And they were even less understood by the other group, the supernaturalists. Stahl and Hahnemann, the successors of Paracelsus, maintained that the "chief symptoms, or the totality of the symptoms, constitute the disease and * * * is only and always a peculiar, vital, dynamic derangement of the health," and "disease will not cease to be spiritual dynamic derangements of our spiritual vital principle."

The pendulum swung thus from one extreme to the other in the medical systems, founded primarily on philosophic speculations, until the beginning of the 19th century, when advances in physical science, especially through the perfection of the achromatic microscope objective by Ehrenberg (1838), served to prove that certain diseases, as *muscardine,* a contagious disease of silk worms, and *favus,* "honeycomb" of the human scalp, are parasitic in character. At the same time, botanists proved that "yeast" was a microscopic fungus, and the idea that fermentation, which had long been regarded as one of the causes of disease, was due to microscopical fungi took hold (Caignard de

Latour and Schwann). Events of tremendous import occurred in this, the Victorian Era, but perhaps the most important was the establishment of the biological theory of fermentation by Pasteur (1857-1863), which led almost immediately to the germ theory of disease. He traced the diseases of beer and wine to micro-organisms other than ordinary yeast invading the fermentable liquid and interfering with the usual alcoholic fermentation by producing undesirable fermentations of their own. It became clear to Pasteur that specific fermentations were caused by specific ferments. The causes of any familiar fermentation and any familiar infectious disease show remarkable similarity. This is shown in tabulated comparative columns below:

A FERMENTATION. (Apple Juice)	AN INFECTIOUS DISEASE. (Small-pox)
1. Exposure of the juice to air, dust, etc.	1. Exposure of the patient to infection.
2. Repose and then slow change. (Growth of the ferment)	2. Incubation. (Slow and insidious progress of the disease.)
3. Active fermentation or "working." Evolution of gas bubbles, change of sugar to alcohol. Rise of temperature.	3. Active disease. Eruption, disturbance of the usual functions. Rise of temperature or fever.
4. Gradual cessation of fermentation.	4. Slow convalescence (or death).
5. No further liability to alcoholic fermentation.	5. Immunity to smallpox.

It was but a step, yet a mighty step, to consider many wound diseases as being due to infections. This step was taken by Sir Joseph (later Lord) Lister, the already eminent Scottish surgeon. By the use of antiseptic precautions, in the way of dressings, instruments, etc., he founded modern sanitary or aseptic surgery, which now gives the surgeon perfect assurance and constant success in the most difficult operations.

The achromatic objective referred to turned many eyes to the study of the "infinitely little germs," one group of which, "bacteria," has become of the first importance to sanitarians and etiologists.

Liebig raised an apparently valid objection to the germ causation of fermentation, asserting that the germs, micro-organisms, microbes, whatever name might be given them, were present as a *result* rather than as a *cause* of fermentation. Pasteur, the "founder" of bacteriology, silenced this objection by the use of

needle inoculations and by producing practically pure liquid cultivations. Not more than forty years ago it was vehemently urged that in the case of diseases it was absurd to attribute them to germs. Koch, however, disproved this and placed bacteriology for the first time on a strictly scientific basis by producing pure liquid cultures of anthrax, by constant continuous dilution and inoculation, and developing his method of "solid cultures." The discovery of the micro-organisms of tuberculosis, Asiatic cholera, diphtheria, tetanus, etc., followed. Thus, within the past thirty years, we have "emerged from the stifling clouds of doubt to take a quick draught of the refreshing air of certainty." It must be confessed, however, that no disease that affects man or beast is thoroughly understood. Furthermore, we know practically nothing as yet of the cause of cancer and little of that of insanity.

Yet it has long been known that spoiled foods were dangerous to eat. Burrows (1814) described a poisonous substance extracted from putrefying fish, Kerner (1820) obtained an atropine-like alkaloid from decomposed albumen, and Panum (1856) secured a product from decomposing animal matter which he called "sepsin." Selmi (1870) gave these so-called poisonous alkaloids the name of "ptomaines" or "cadaveric substances." The harmless ones were called "leucomaines."

Knowing the effect, the cause being demonstrated, the question then arose, how does the cause produce the effect? The invading micro-organisms might produce disease in the animal body either, first, by *physical obstruction,* clogging the capillaries, veins or arteries, thus mechanically interfering with the ordinary functions of the vascular system; or, second, by *chemical interference,* which could be either a robbing of the body of its food by the invaders or the generation of toxic substances which poison the animal system.

"It is not merely the body of the patient that is invaded by germs; our theory goes much farther than this and shows us the germs growing, dividing and multiplying in the body of the patient, while at the same time each carries on its individual metabolic existence, acting upon its immediate environment, drawing to itself foods, and reacting by setting free the special products of its vital activity." The life history of the alcoholic

ferment in action, already cited, shows the production of a distinct substance, alcohol. It is not enough to suppose that the micro-oganisms in question mechanically obstruct or physically disturb the delicate machinery of the living organism in which they multiply. The symptoms of infectious disease are rather those of toxic actions, actual poisonings of body, accompanied by chills, fever, delirium and other symptoms of a profound disturbance. Moreover, the phases of infectious disease—the slow onset, the active illness, the recovery and the subsequent immunity—are all readily explained upon the modern theory of *zymotoxic* action or *"ferment-poisoning."* In fact, Nencki and Brieger have prepared these "toxins" from pure bacterial cultures. The dreams of the iatro-chemists have come true.

We know these infections "have the peculiar character of suddenly attacking great numbers of people at intervals in unfavorable sanitary conditions . . . have influenced not only the fate of cities, such as Athens and Florence, but of empires; they decimate armies, disable fleets; they take the lives of criminals that justice has not condemned; they redouble the dangers of overcrowded hospitals; they infest the habitations of the poor, and strike the artisan in his strength down from comfort into helpless poverty; they carry away the infant from the mother's breast, and the old man at the end of life; but their direct eruptions are excessively fatal to men in the prime and vigor of age." Further than that, we know that some of these zymotoxic diseases steal on in guises the most innocent and least suspected by those most liable to the ambush. This is especially true of tuberculosis, the white plague, in the fight against which every citizen should enlist, a fight in which every good citizen does enlist.

The main avenues by which pathogenic bacteria or their products reach the human system are, first, air; second, water; third, food; and fourth, clothing. These are to be discussed in some detail by experts in subsequent chapters. Reference is made to them here only in so far as may be necessary in the development of the theme of this chapter.

We may accustom the body to do without clothing, but it is not the fashion in thickly populated cities. And Dame Fashion is an exacting mistress at times. Men have fasted for more

than forty days; shipwrecked sailors have been known to live after being deprived of fresh water for six days; but recovery is rare for man when he has not tasted God's oxygen for five minutes. Three-quarters of the body are water; a notable percentage is food, apparently good food for certain African tribes with cannibalistic tendencies; but we possess small air tanks. Even were we provided with these, we should require a posterior, anterior, or lateral extension 20 x 15 x 10 feet to hold enough air for one hour, provided it were under the ordinary atmospheric pressure. To convert food into energy practically we require about fifty times as much air by weight. Normal air, when inspired, contains about 0.04 per cent. of carbon dioxide and 21 per cent. of oxygen; when expired, about 4 per cent. of carbon dioxide and 17 per cent. of oxygen. A candle ceases to burn in the air when the percentage of oxygen gets below 18. We can readily see what this means when a number of people in a room are breathing the same air over and over again. After the battle of Austerlitz, 300 prisoners were placed in a poorly ventilated room. Of these, 260 died before the next morning. Each individual in a room should have 20 cubic meters of fresh air every hour. In connection with the problem of overcrowding, there is a concomitant circumstance, namely, the use of dark rooms for sleeping. There is an Italian proverb which says, "where the sun does not go, the doctor goes." This is a sad commentary when we realize the tendency of emigrants to swarm in our cities.

There are many incidental impurites in the air that are local and more or less evanescent. I have shown that in the City of New York over a thousand tons of sulphur dioxide are poured into the air daily in the combustion of coal. Without smoke-consuming devices there may be more or less soot, along with the dust whipped up from the streets by the winds. Aside from the personal discomfort from flying particles of solid material, whatever be its nature, these particles are the bearers of germs, many of which may be pathogenic. In many cases it is from the dried sputum of the thousands of spitters on our streets. Sedgwick has shown that 10 liters of air taken 5 feet above a macadamized street in a dust storm may contain as many as 200,000 micro-organisms. Air free from solid particles is free

from bacteria. We may minimize spitting, but we cannot stop it. The streets should therefore be either made dustless or wet down with dilute chlorine water, that is, a solution of bleaching powder, or other disinfecting fluid. Furthermore, it is to be hoped that the Public Service Commissions will allow the

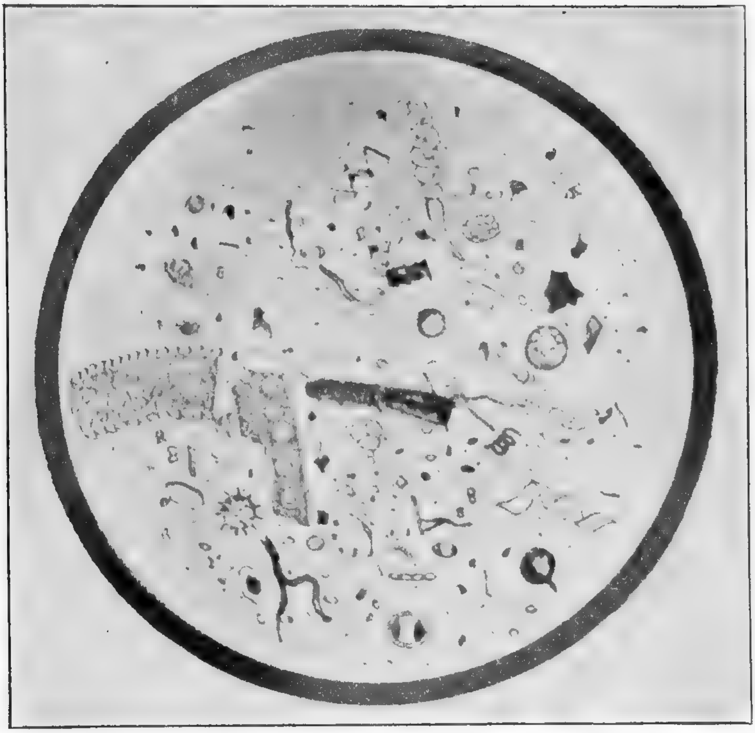

FIG. 5.—DUST PARTICLES IN THE AIR OF A TOWN.
(Highly Magnified).—Smithsonian Institution Report.

construction of no more subways except that the tracks be separated by partitions, or that the tracks of trains going in opposite directions be kept in different compartments. For although much street air enters the tunnels in New York at present, a large portion of the air is simply churned by the passing trains and not quickly and properly replaced.

The necessity for a suitable supply of potable drinking water is now well recognized in every civilized community, and it is usually provided in the city, often at great expense, yet an appall-

ing degree of ignorance is still encountered in the country districts that is difficult to overcome. A large percentage of urban population, and it is most desirable that every single individual in the city should, enjoy a few days or weeks in the country in the summer. The ignorance of country habits is proverbial with the urban citizen, who takes certain matters for granted. It is, therefore, not infrequent that these outings, picnics, etc., which should make for the better health, are the direct causes of unnecessary illnesses attributable directly to the drinking water, for all the liquid refreshments on these occasions are not limited to the national German beverage.

A land should be looked upon as watered by its smaller lakes, its springs, and its brooks. The provision of a potable water

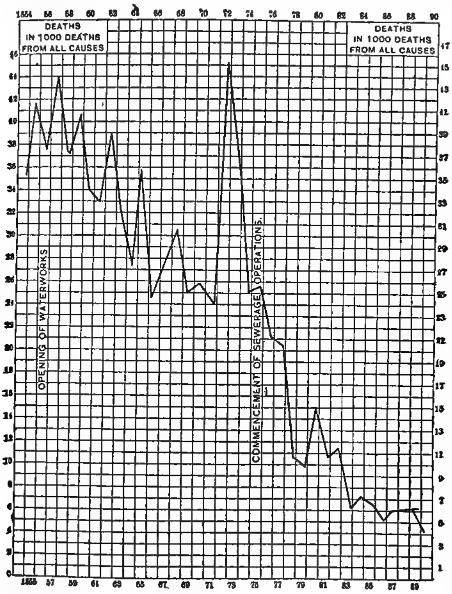

FIG. 6.—TYPHOID MORTALITY IN BERLIN (ROECHLING).
As affected by the introduction of a potable water supply and subsequently an adequate sewerage system.

for a municipality is a great gain, and is being provided for our city at an enormous expense, but it must be accompanied with proper sewerage. Dantzic had good water in 1869, but the typhoid rate did not decrease materially until 1872, when sew-

ers were added. Vienna had good sewerage and bad water up to 1874; the death rate from typhoid was 340 in 100,000. That year good water was supplied and the rate dropped to 11 in 100,000. With good water and no sewerage, the soil becomes saturated with refuse matter, a hot bed awaiting the planting of pathogenic bacterial seed. Sedgwick, referring to cholera, figuratively states that "Pettenkoffer has given the key to the whole situation by saying that filth is like gunpowder, for which cholera is a spark. A community had better remove the gunpowder than try to beat off the spark; for in spite of their efforts, however frantic, this may at any time reach the powder, and if it does is sure to blow them to pieces."

While a land should be looked upon as watered by its lakes, its springs and brooks, a land should be looked upon as sewered by its great, especially navigable, rivers and canals. For various reasons, topography, extremes of weather, enormous expenditures necessary, and so forth, many principal water supplies must be drawn from these sewers, which are direct continuations of the intestine. We cannot hope to have the lower Hudson river free from some sewage as long as inhabited tow and passenger boats ply to and fro and ocean-going vessels moor in our harbor or dock at our piers. Recent accounts in the public press have drawn attention to the serious pollution of the harbor by sewage from the city alone. As Faraday said of the filth of the Thames, "If we neglect this subject we cannot expect to do so with impunity." The sewage problem of the coming greatest New York awaits a solution. "The sewage question resolves itself into this: What is the cheapest and most efficient technical process for rendering human excreta useful instead of dangerous?" (Krepp.)

Half the cost of living goes to pay for food. The centralization of population requires its transportation to the centers. For a century it has been known that certain kinds of food could be preserved for later consumption without injury to health. There is no objection now to the preservation of food, provided it is done in the proper, that is, harmless manner. The adulteration and sophistication of food are outgrowths of the development of the city and the improved means for world-wide transportation, coupled with the degeneracy of those who

live by bartering and their desire for luxuries. The chemist has been the Cartouche and Sherlock Holmes in the abominable business. Yet ignorance and disregard for the consequences so long as gain resulted have been behind the supply of one particular food, milk, which is the main support of the weak and helpless. The government has formulated satisfactory laws against the adulteration of the coin of the realm and enforces them vigorously. We have food laws now, but they are not satisfactory, nor are they always properly enforced. In fact, they cannot be enforced as long as they admit of constant quibbling as to the meaning of common words in our language. No doubt these objections will be removed, for it is a time of fuller awakening to the conscience of our civic value.

Clothing which has been exposed to such infectious diseases as diphtheria and smallpox is now destroyed or duly disinfected, at least theoretically. This is not the case with clothing, either second-hand or new clothing, made in the sweatshops, where we know tuberculosis is rampant. It thus serves as a means for the spread of infectious diseases. This can be stopped by requiring new clothing to be thoroughly disinfected before allowing it on the market, or, better, by applying the old Mosaic law enjoining the strictest cleanliness. Moses really anticipated our modern sanitary laws, for cleanliness is the beginning and the end.

There is such a thing as the philosophy of cleanliness. Dirt is dangerous, not because it is of the earth, earthy, but it is too often "drit." The desire of cleanness, or the disgust for dirt, has gradually become established with all highly civilized peoples. Cleanness is not merely an æsthetic adornment, though doubtless an acquired taste. It is above all a sanitary safeguard, and has been learned by dearly bought experience. To be clean is in a measure to be safe from infectious diseases, and cleanness applies not only to the individual, but to the personal environment.

The aim of every citizen should be to make the city clean; the city healthy; the city beautiful.

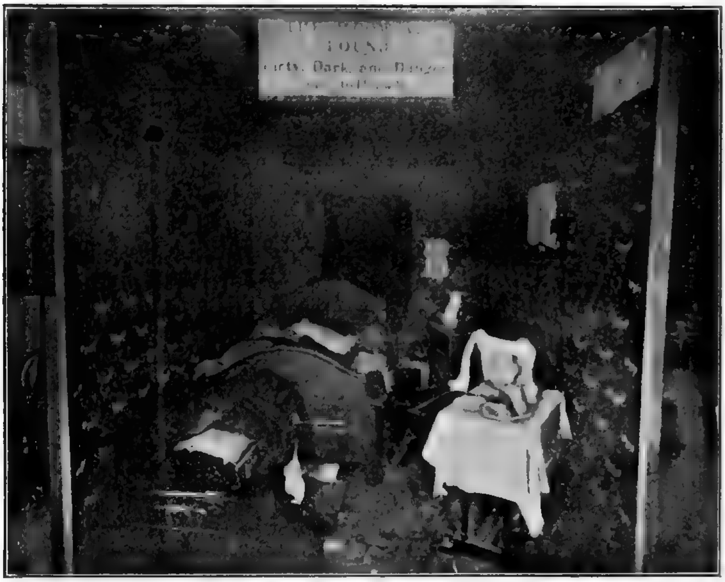

FIG. 7.
(Courtesy of the Committee on the Prevention of Tuberculosis in New York City.)

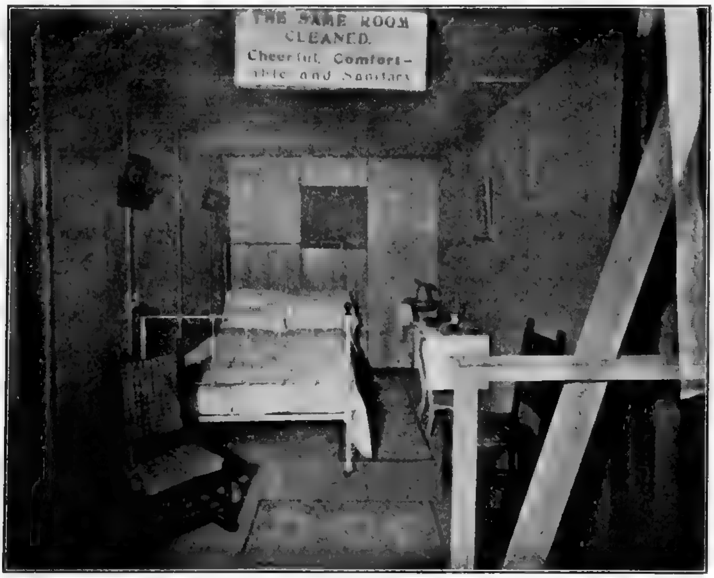

FIG. 8.
(Courtesy of the Committee on the Prevention of Tuberculosis in New York City.)

FIG. 9.—MODEL BEDROOM, CLEAN AND WELL LIGHTED.
(City and Suburban Homes Co., New York.)

FIG. 10.—MODEL KITCHEN WITH FAMILY LAUNDRY ARRANGEMENTS.
(City and Suburban Homes Co., New York.)

FIG. 11.—MODEL SITTING ROOM PROVIDED WITH AMPLE AIR AND LIGHT.
(City and Suburban Homes Co., New York.)

CHAPTER II

Drinking Water and Disease.

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This topic is admittedly too large to be disposed of in a single lecture, and the most that can be done will be to glance over some scattered portions of the field. One very practical point must be referred to at the outset, and that is, engineers must not only attend strictly to the technical portions of their work, but they should ever bear in mind that they are to protect the health of the numbers of ignorant laborers committed to their care. Civil engineers in particular have a double responsibility, for it is their duty not only to look after the health of their employees, but to also guard against the very real danger of contamination reaching some neighboring town's water supply, by reason of their laborers camping upon the water-shed. Many an epidemic has been traced to such a source of pollution.

The water purveyor should be rated as a kind of sanitary officer. At times he becomes an epidemiologist, and it is then his duty not only to show the people that the water he supplies is beyond suspicion, but to earnestly seek the cause of the disease which may have broken out from another source. He must, in short, put his finger upon the origin of the difficulty. Is the milkman to blame? Has an accident allowed contamination within the city limits? Or is a disease "carrier" at the bottom of the trouble? Disease other than typhoid may be distributed by "carriers," but into their activities beyond the entire field the active interest of the "water man" does not go.

The sanitary inspector must consider the possibility of the spread of disease by flies. When I was a boy, the belief existed that the presence of many flies tended toward a healthful summer, because they were held to be the means of removal of much waste material which would otherwise decay and taint the atmosphere. We now know that flies are a source of danger in that they do not wipe their feet before crawling over our food.

In this connection note the disastrous typhoid fever outbreaks in our military camps during the Spanish war. These epidemics were occasioned by the inoculation of food by flies; flies that visited the latrines first and the kitchens afterwards.

It is the possibility of the more or less direct addition of sewage material to a public supply that commonly demands the attention of the water expert.

The relation of disease to sewage-polluted water is too widely admitted to need restatement here, but there are a few classic cases that cannot be too frequently commented upon, and their celebrity must serve as an excuse for recalling them to the reader's attention.

All have heard of the cholera epidemic at Hamburg, and will recall how the cholera cases singled out the old city of Hamburg from the adjacent communities of Altona and Wansbeck. That

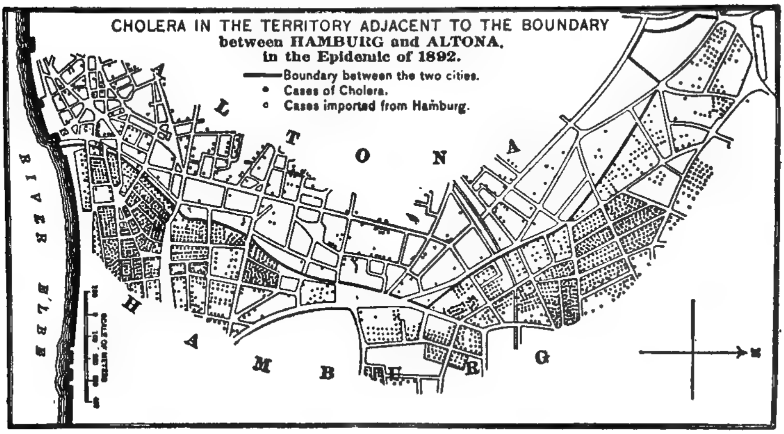

FIG. 12.
(Taken from Mason's *Water Supply.*)

great center of population, 900,000 in all, consists of the three municipalities mentioned, so grown together that the boundary lines between them are not recognizable by a stranger. One can no more tell when he leaves Hamburg and passes into Altona than he could tell when he passed from one ward to another in the city itself, and yet the invisible boundary was not crossed by the disease, and for the simple reason that Hamburg used raw Elbe water and Altona carefully filtered the same

before serving it to its people. It would be difficult to get a better instance of the relation of a drinking water to disease.

Plymouth, Pa., furnishes another illustration of a somewhat different type. The dejecta from a single typhoid patient was thrown out upon the snow of a frozen hillside which sloped towards a stream supplying the city reservoir. After lying for weeks in a frozen state, the infected material was washed into the stream upon the occasion of the March thaw. Most disastrous results followed and typhoid swept the town. Note, please, the danger to a community that may come from a single mismanaged case; also observe that the winter freezing did not suffice to kill the germs; and note further that the location where the waste material was thrown was a steep and frozen hillside which afforded every opportunity of quick delivery of pollution to the stream itself, as soon as the surface was softened at the time of thaw.

I am particularly anxious to call attention to the lay of the land and its character, for the simple reason that the Plymouth case was thought of as a possible answer to a somewhat similar condition of affairs occurring near Meridian, Miss. In the latter instance the element of safety, however, lay in the facts that the ground was not rocky, but was of a sandy character, the slope was by no means steep, the soil could not be hardened by the frosts of winter, and the material was buried to a slight degree instead of being thrown upon the surface under circumstances permitting of accumulation. In the southern case, soil filtration with its benefits was possible; in the Plymouth case such advantages did not obtain.

The epidemic of typhoid at Maidstone, England, may possibly be new to the reader. It was caused by the contamination of ground water by the dejecta of a large number of hop pickers, who camped upon the ground and who lived in the open during the picking season. It may seem strange that serious infection of the water could occur under such circumstances, and one is naturally prone to ask why did not soil filtration take care of the surface pollution. The answer is that there had been a long period of drouth and the heavy clay soil was very badly cracked, so badly, in fact, that the bottom of the crack would be often beyond the reach of a long stick. Is it to be wondered

that under those circumstances a heavy rain washed infected material through these cracks directly into the drains of the water system lying a few feet below? No advantage of that powerful purifying process known as intermittent soil filtration could obtain in such a case, and the result was as might have been expected—disaster.

Just one more instance if you will allow me. A celebrated school derived its water supply from a carefully drilled, carefully located, and carefully tubed deep well. The sewerage system of the establishment had been planned by an expert. Suddenly a serious outbreak of typhoid fever occurred among the students. Upon investigation it was found that a broken sewer pipe permitted sewage to pass into the annular space between the well's sides and the tubing. Of course, the water supply became badly polluted. Please note this peculiar point: the victims of this outbreak were poisoned by a sewage from a supposedly non-pathogenic source, for there was no record of previous typhoid at the school.

A form of water contamination that has but lately risen to notice is that furnished by railroads. When one considers the great number of people that pass over a measured mile of road-bed per year, and knowing as we do that a certain percentage of these must be carrying typhoid germs with them, it is not surprising that objectionable results should obtain in some instances, in view of the fact that human excreta will fall upon the road-bed from passing trains and be washed therefrom into sources of water supply when the lay of the land is favorable. A somewhat unusual case came up for the writer's consideration—a case dealing with the future rather than with the present condition of affairs. It originated in a proposition to build a railway embankment across the site of a proposed reservoir and upon the watershed then in use for supply purposes. Comparison was made between such a proposed construction and the already existing line of railroad that skirted the reservoir site. The writer's criticism was this: the proposed line of railroad would be more dangerous than the existing one, first, because it would have two slopes to its embankment, therefore making it more difficult to care for polluting material thrown upon the road-bed; and secondly, there would be danger arising from the labor-

ers working upon the site during the period of construction. Should you ever be called upon to guard a water collecting locality from danger incident to the presence of a railroad, you must remember that in northern localities you must so formulate your rules as to make them cover winter conditions as well as those of summer. Frost will seal a railway embankment, and, unless attention be given the case, the conditions which produced the Plymouth outbreak may be repeated.

It is especially desirable that trestles and bridges crossing the line of direct supply should be so protected as to prevent polluting material dropping into the water from passing trains.

A consideration of the contamination possible through the agency of railroads brings to mind the broad topic for the necessity of a thorough "sanitary survey" before deciding upon the fitness of water for domestic use. Too much stress cannot well be laid upon this point. The water expert judges of the character of a water, not only from the chemical and bacteriological data, but from those of the sanitary survey as well; and it is scarcely too much to say that if the last be wanting, the first two are wellnigh valueless. A laboratory knowledge alone will often lead to most unfortunate results. One instance will serve to drive the lesson home. A city which I have in mind was sadly in need of a proper water supply to replace the grossly polluted one then in use. An abundant and excellent water was, by good fortune, secured from an artesian source. The city fathers took a sample of that water and packed it off to be examined at a laboratory hundreds of miles away. The packing was not in ice. The few harmless bacteria which were present originally had every opportunity to multiply during the journey, and the report was returned showing the presence of an immense number of germs per cubic centimeter. Upon the strength of that report the new supply was abandoned. Was it wise for the man who examined that water to report as he did, knowing that the water had been sent from a distance? Reports of that character are not rare, and they do much harm.

Again, the "sanitary survey" is of use in that it aids one in prophesying what a water may be like in the future, and it paves the way toward a safeguarding of the sources of supply. Apropos of this matter of prophecy, the writer is prone to throw

a little of it even into the analytical field in the shape of a determination of what the water will likely do to the more common metals should it be brought in contact with them. It is his custom after analyzing a water to determine how much zinc, or copper, or lead, in parts per million a water will take up after the metal has been exposed thereto for one hour at 15° C., the surface of exposure being 1 sq. decimeter per liter of water. Suppose that a man were contemplating piping a spring water through several miles of pipe. Should a report of the water's action upon zinc be available before understanding the work of construction, he would be in a position to determine whether or not to use galvanized iron. An interesting case of this kind came under the author's observation. An expensive plant had been laid down in the absence of a knowledge of how the water would act upon zinc, and it was subsequently discovered that a much smaller outlay for black iron pipe would have given better results.

To revert once more to the "sanitary survey," population, especially summer population, increases along lake shores, and rules must be formulated to safely dispose of the resulting refuse. The incorporation of such rules in the report is proper and is commonly expected, but let me suggest that they be not made too academic. An artist was once asked how he mixed his colors. His answer was that he mixed them with brains. Reports should be written with that answer in mind. They should be filled with clear common sense. My advice is: do not push for a degree of purity so extreme as to be non-practical, always remembering that it is legitimate to ask your clients to assume a reasonable degree of risk themselves rather than seek absolute safety at ruinous cost or by manifest injustice to their neighbors. Reasonable risk is properly encountered in daily life on every hand. We could probably increase our span of life by wearing some device for sterilizing the air we breathe, but would our lengthened days be worth the price? We could also, doubtless, much improve the tuberculosis situation by killing all the consumptives now living, but such action would be extreme, unfair, and, of course, unpopular.

Let us now change our topic somewhat. When investigating typhoid epidemics, one is sometimes struck by the dif-

ference between the intensity of the disease in some instances and its mildness in others. Broadly stated, one finds that the more recent the pollution the more severe the attack. Typhoid epidemics following the use of polluted river water are commonly mild in character, while isolated country cases of the disease are often severe. A reasonable explanation would seem to be that, while the adverse conditions of river carriage supply abundant opportunity for the pathogenic germs to either die or to at least lose a portion of their virulence, the conditions governing the use of water from an infected well usually admit of a shorter period of time elapsing between the entrance of polluting material and the drinking of the water. In other words, the struggle for existence during stream transmission will cause a decrease in the "poisoning power" of the typhoid germ, which decrease will vary directly with lapse of time, and will consequently be a function of both distance and velocity of flow. Bacilli, therefore, which started on their journey in vigorous health might be considered as arriving at the point of invasion in a state so enfeebled as to be incapable of producing a "normal" type of disease. Thus, the writer found that in 75 typhoid epidemics due to well waters the average death rate was 11.83 per cent., while in 33 epidemics due to stream and reservoir waters the death rate was 9.85 per cent. And again, in a mixed epidemic, due partly to the water of a polluted stream and partly to water derived from contaminated wells, the ratio of severe cases to total cases stood: Stream water, 27.8 per cent.; well water, 56.5 per cent.

It is an odd fact that typhoid outbreaks are often preceded by a general prevalence of diarrhœa. That was notably so in the Maidstone attack. The milder disorder has a shorter period of incubation, and thus shows its presence sooner. If the danger flag be disregarded, more serious trouble may be found later.

Referring to the expression "incubation period," just used, the time commonly given for typhoid fever to make its appearance is 14 days after infection. Dr. Leal has adopted what he calls the "report" period. By it he means that the disease will get to the attention of the people three weeks after the arrival of the infection, the extra week being due to the usual delay in reporting the cases.

In active practice one is asked to judge all sorts of water, hard and soft, clear and turbid, colored and colorless. Even temperature variations will come into consideration, because a cool water lowers the ice bill and greatly benefits the poorer portion of the people. Each case must be handled upon its own merits, having regard for the peculiar demands of the problem at hand. All dogmatisms must be avoided, as well as all attempts to make a too general rule fit a particular condition.

A water company should not, of course, furnish a mineral water for a town supply, but we must bear in mind that a reasonable degree of hardness is allowable; for instance, some calcium sulphate will be of advantage to the brewing industry, as in the case of Burton-on-Trent. Should the laundry or boiler interests be large, as at Troy, N. Y., then a soft water will be imperative. If the medical fraternity insist upon softening a very hard artesian water because of doubt as to its action upon the human economy, it will be for us to determine the cost of such improvement as compared with that of filtering a reliable but heavily stained surface water that may be had at small expense. Filter it we probably must if we decide to use it at all, because, although we do not connect disease-producing properties with the stain present, yet the public is now demanding a good looking water as well as a safe one, and their demand is reasonable. In fact, we are living closer and closer to the general rule that a surface water should be subjected to some efficient form of purification before being pronounced fit for public supply. Of course, there are proper exceptions to this rule, and it is for the water expert to pronounce when and when not an exception should be made.

Density of population is increasing and waterways are under greater and greater risk of contamination. Rivers drain the land rather than water it. They cannot help but do so, as they lie in the valleys, not along the mountain tops. It is to the common interest that such drains be kept in as good condition as circumstances will permit, and we should discourage any attempt to unnecessarily pollute them, especially avoiding their becoming nuisances; but while safeguarding, so far as may be, the interests of those who require good water, we must not forget that the communities which seek to dispose of municipal waste also have rights, and that their burdens should not be made unduly

heavy. Should we venture in sanitary reform as far as Rideal would have us go, it would little matter how badly our rivers became polluted, always assuming that they did not pass the limit of becoming physically objectionable. He approves of installing, as a part of each household, fittings which would insure sterility of the existing water supply, and suggests Pasteur filters and heat sterilizers under proper municipal control. Such an arrangement would be manifestly impossible, as the ignorant portion of the community must be supplied with a water which is "safe from the faucet."

One of the most common forms of criticism which water engineers ever meet may be termed the "test of experience." It is constantly appealed to in support of the alleged purity of some favorite water, and the plea that "my family has used the supply for a half century" is considered an argument beyond danger of refutation, it being overlooked that a family, or even several families, can not furnish a sufficient number of persons to make the "experience test" valuable; for, be it remembered, a water known to be dangerously polluted will not transmit disease to all or nearly all of those who drink it. As a matter of fact, when one considers the question from a numerical standpoint, basing his investigation upon the population of a large community, the conclusion is forced upon him that the per capita danger from polluted water is really small. Thus in a city of 100,000 inhabitants which I have in mind, the high typhoid death rate, manifestly caused by bad water, was about 90 per year, which means that over 99,000 of the people did not have the disease at all.

Now, how about this great majority of the citizens that escape? They would not be likely to testify as to the dangers of the water supply. The risk is small, and it takes a large community to make data about it valuable, but, relatively small though it be, it nevertheless is a good investment for a city to avoid it, because human life has a money value, and the town which cuts its typhoid rate in half by the erection of a filter plant receives very quick return for the funds expended.

Doubtless one reason why so many people deny the existence of danger lurking in some specific drinking water is because of the non-dramatic character of the attack.

Let us suppose that a city has a yearly typhoid rate of 75, which means that 750 people per 100,000 inhabitants have the disease each year, and that 75 of them die. The impression upon the community is not really felt except by those whose homes are invaded, and the remainder of the population would be likely to resort to the old story, "We have used the water for years without harm," etc., etc. What do you think would happen in such a city if some public utility were so badly managed as to kill 75 people every year and injure 675 others? Do you fancy it would be long before there would be mob demonstration in such a case? Would the people who had been injured be likely to listen with patience to such of their neighbors as claimed that because they had not been damaged they doubted if there were any real mismanagement after all?

Truly, the "test of experience" is a tiresome and dreaded argument which the water expert is forced to meet. Tiresome because he meets it so often, and dreaded because he feels he must go on meeting it to the end of his days. The time is clear in my memory when we had to close polluted city wells after midnight for the simple reason that enthusiastic users of the water would have protected their old street pumps by a resort to violence if necessary.

To those who supervise the water supply, I say, much as you may fear the two great water-born diseases, typhoid fever and Asiatic cholera, and many as may be the sleepless nights that the safeguarding of the public supply from them may cost you, your real trouble will come from another, a more frequent and a perfectly harmless cause, viz., the production of taste and smell by reason of the growth in the water of oil-secreting algæ.

These little plants sometimes develop in immense numbers, and the result of their growth and decay, being readily detected by the senses, will produce widespread dissatisfaction, and your office will be at once deluged by complaints. The public believes what it sees and smells and tastes, and will indignantly protest against using a water offensive to either nose or palate, although they will be perfectly willing to drink one pleasant to the eye, however much it may be loaded with the germs of disease. I am reminded of the ruling of a Mississippi chancellor in a case with which I was once connected. His honor threw all the

expert testimony out of court with the remark that it was not necessary to treat with special consideration what experts might have to say upon the subject, as the ordinary citizen is well able to tell whether or not a given water is fit to drink. To illustrate how far the court fell short of the truth in this instance, let me say that a few years ago the clear and bright effluent from a city's sewage septic tank was placed in a show window in another town alongside of an exhibit of the local water supply, to the apparent disadvantage of the latter. Poor as the town water was, it could scarcely have been fair to compare it with filtered sewage, and yet his honor from Mississippi would have judged otherwise.

I repeat to those who hear me, or read this, and to engineers, you will be asked to pass upon the suitability of waters of great variety of composition. Do it with care and caution after informing yourselves as to the character of the source whence the water comes and the immediate surroundings of the same. No description of a spot will serve your purpose. You should see it for yourselves. A man now deals with the data of water examination in a broad-gauged fashion, feeling that the day has gone by for blind adherence to cut and dried standards. He approaches his decision pretty much as does the medical practitioner frame his diagnosis at the bedside. It may be that the symptoms of a patient do not accord with the description of the disease as found in books, and the practitioner's attention may be called to those discrepancies by a coadjutor more recently from the schools; nevertheless, the breadth of his experience assures the more mature man that his judgment is not at fault, and it is experience that is of value in the end.

No matter how excellent the plan for watering your city may be, it will have its opponents as well as its advocates, and its power of supplying wholesome water to the public will be probably strongly denied by the former party. Remember that you are men of special training, who have devoted much of your time to the consideration of water questions, and who have brought to your aid a sufficiency of chemistry, bacteriology and microscopy to satisfy the requirements of your calling. You are, because of your special training and experience, enabled to view the question at issue from more than one side, and your con-

clusions are, in consequence, entitled to greater attention. Suppose that while addressing a city council upon the advisability of erecting some special form of filter for the purification of the public water supply, you are interrupted by a councilman who states that all the physicians in the city are opposed to such a plant, and that, therefore, how could the council, being composed of laymen, run counter to such weight of professional opinion. The answer should be simple and emphatic, viz., that upon such a subject the physicians were no less laymen that the councilmen themselves, and that opposition from them should have no greater weight than from the lawyers or the clergymen of the town.

Years ago it was the custom for the water analyst to be instructed to search for the typhoid bacillus, and his negative report was considered a final pronouncement as to the safety of the supply. After a while we found that it was common enough to fail to detect a typhoid germ when we knew it was present. As a result the search for that particular organism rapidly fell into disfavor. Now it seems to be coming to the front once more, and we may be approaching a time when we will again test for the typhoid organism as a part of our routine examination, and do so with far greater certainty of finding it should it be present.

I was asked the other day if, in the event of a technique being so perfected as to make a decision relative to the presence of the typhoid organism beyond question, search for the commoner intestinal organisims would be then rendered superfluous. There can, I think, be but one reply, and that a negative one, for the reason that it is always desirable to be able to recognize sewage pollution, even when it comes from non-pathogenic sources.

In view of what has been said we may properly ask, What is to be done with typhoid dejecta beyond treatment with a suitable disinfectant? What final disposition can be made of such material? Considering the fact that the upper soil, viz., that portion which the farmer utilizes, is swarming with bacteria, what better disposition can be made than a shallow burial, upon level ground, on a site selected with such judgment as to prevent contamination of neighboring ground-water sup-

plies? We have seen the immense power of intermittent soil filtration abundantly demonstrated, and there is good reason to believe that if the dose of polluting material be not too large for the site selected, and if a second dose should not follow after too short an interval of time, then Nature's process of purification may be relied upon with confidence.

CHAPTER III

Municipal Water Supply, with Especial Reference to New York's Catskill Mountain Waterworks.

ALFRED DOUGLAS FLINN, S.B.,

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With continuing rapid growth in population and industries, the metropolis has outgrown the water systems which have supplied it for many years. These well-known Croton and Ridgewood systems will continue to contribute permanently, and their waters should be carefully conserved and protected, but the time to supplement them has fully come. Sundry investigations looking toward the anticipated extensions have been made by individuals and commissions, accumulating a large mass of data, culminating in the voluminous printed report of the Burr-Hering-Freeman Commission to Mayor Seth Low, in 1903. Eventually, in 1905, through legislative enactment, the State Water Supply Commission and the Board of Water Supply of the City of New York were created, the former to control water supply undertakings throughout the state and the latter to construct new works for New York City*

General Description of New Water System.—Legal limitations curtailed the city's field of selection. As being most available, economical and suitable, a group of streams in the Catskill mountains was selected. Among them Esopus creek was chosen for immediate development, the Rondout, Schoharie and Catskill creeks being reserved for later development as needed to keep pace with growing demands. These four drainage areas, with several adjacent smaller gathering grounds, have a total area of 940 square miles, for the most part sparsely populated and largely wooded. From them it is conservatively estimated that 830 million gallons daily can be obtained. Esopus watershed has an area of 258 square miles and can safely furnish, even

*The members of the Board of Water Supply began their labors in June, 1905, and during that summer selected a number of men for leading places on the Administration and Engineering staffs. August 1, 1905, the Chief Engineer and the writer assumed their duties and began actively the organization of the Engineering bureau and preliminary studies for the choice of sources of supply and location of works. In October, 1905, after 2 months' work, a project was submitted by the Board to the city government and the State Water Supply Commission for approval.

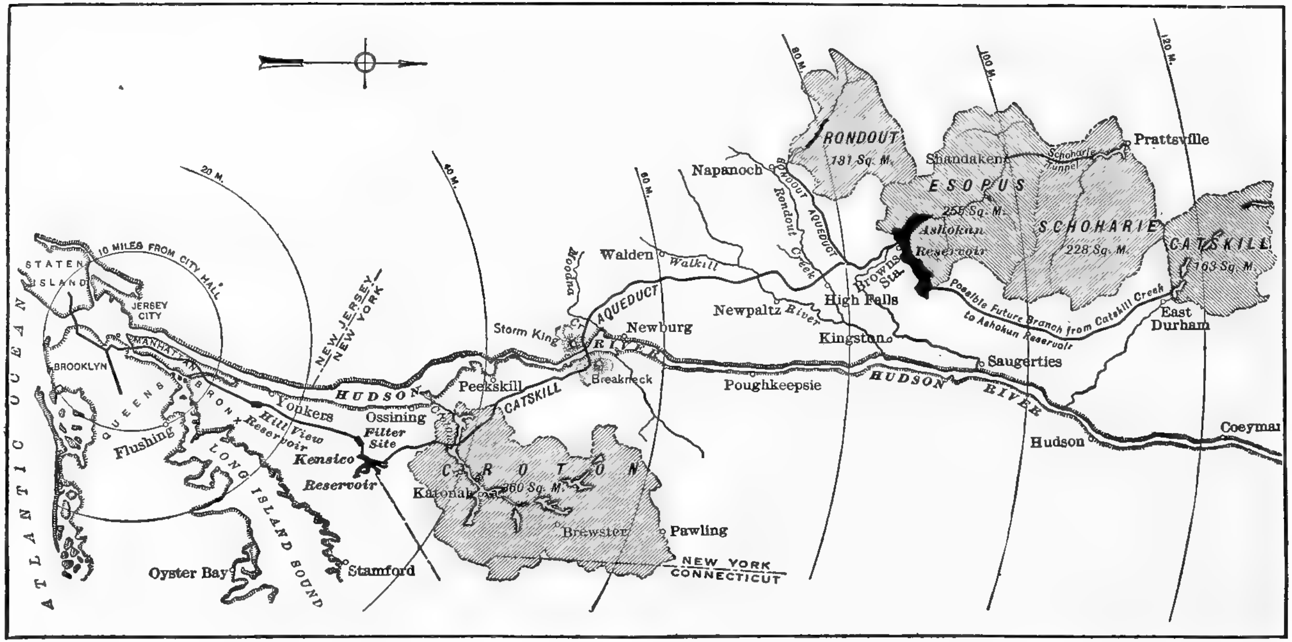

FIG. 13.—MAP OF THE CATSKILL AQUEDUCT SYSTEM.

The shaded sections west of the Hudson indicate the watersheds which fill the Ashokan and other reservoirs. At Storm King a tunnel aqueduct will pass under the river to Breakneck; thence the aqueduct will cross the southwest corner of the Croton watershed to the enlarged Kensico reservoir, south of which is shown the site for the filters, and farther on the great equalizing Hill View reservoir.

(Courtesy of The Century Co.)

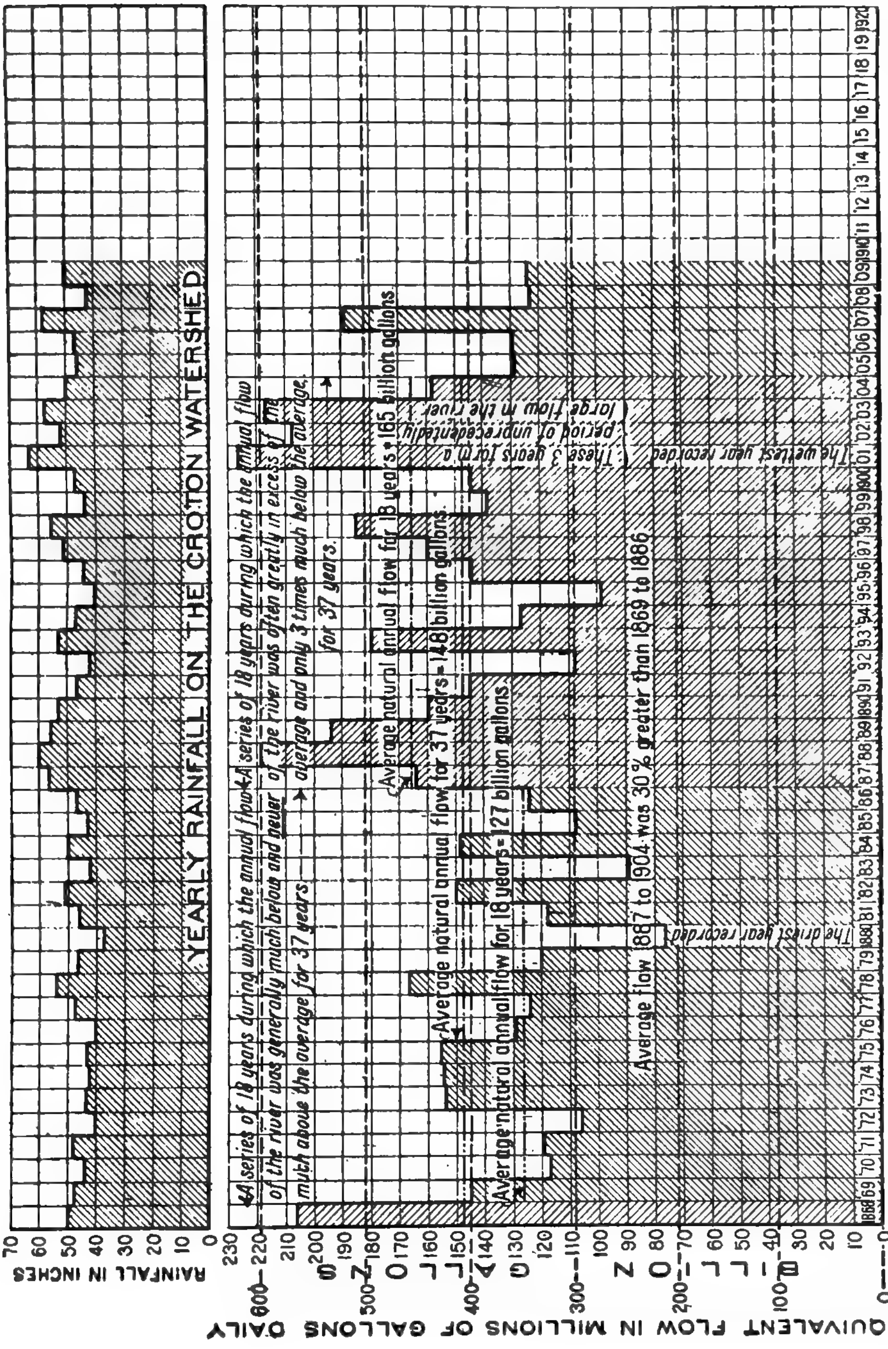

FIG. 14.—CHART SHOWING A STUDY OF THE RAINFALL IN A WATERSHED (CROTON).

The distances between these heavy horizontal lines and the bottom line indicate the total quantities of water which would naturally flow during the given years in the Croton River at the site of the New Croton Dam, allowance having been made for the effects of the reservoirs.

in a series of dry years, 250 million gallons daily. The water of these streams is of excellent quality, and with reasonable safeguarding and simple treatment should remain so. An accompanying map shows this territory and its relation to the city and the Croton watershed.

Naturally, the quantity flowing in a stream differs greatly at various seasons of the year and from year to year. This is strikingly shown by the diagram of the annual flow of Croton river for 42 years, and another giving the monthly flow of Esopus creek for a few years, with rainfalls. To equalize these

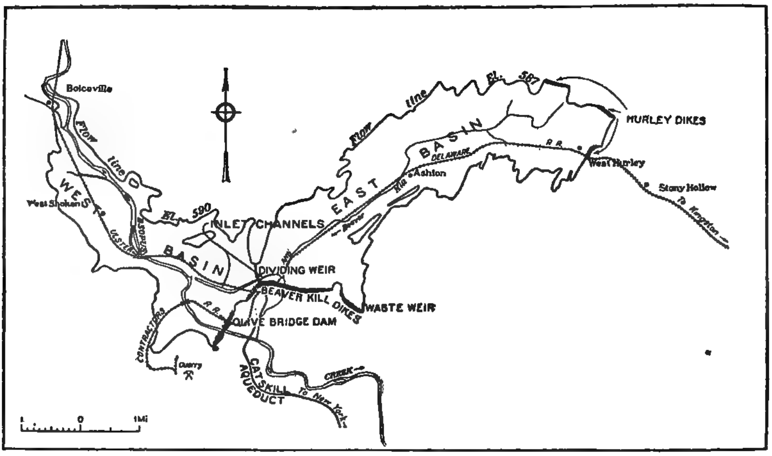

FIG. 15.—MAP OF THE ASHOKAN RESERVOIR.
(Courtesy of The Century Co.)

natural flows of the Catskill mountain streams so as to meet the more nearly uniform consumption of the city, several large impounding reservoirs are to be built, in which the excess waters of freshets can be conserved.*

To convey the water from the gathering grounds to the city, the Catskill aqueduct is being built from Ashokan reservoir

*For the Esopus only one reservoir is needed, but it will be the largest of all. It has been named "Ashokan," which in Indian signifies "place of fish." This artificial lake will be 12 miles long, with a maximum width of 2.6 miles and an area of 12.8 square miles. Its average water depth will be 50 feet, attaining a maximum of 190 feet at the principal dam. When full, its water surface will be 590 feet above mean sea level in New York harbor. To retain the water in this reservoir, earth and masonry dams aggregating 5.4 miles in length are being built, and a dam 2,200 feet long will divide it into two basins. Comprehension is aided by comparisons. The dams would extend across Manhattan Island's widest part three times, and the 128 billion gallons which the reservoir will hold would flood the whole island to a depth of 28 feet, or to the third story window sills. The detail map of this reservoir shows its shape and the situations of the dams.

to the hearts of Brooklyn, Queens and Richmond boroughs, passing through the Bronx and Manhattan. From the head-works to the proposed Silver Lake distributing reservoir on Staten Island the length is 119 miles, of which 54.9 miles are concrete masonry conduit built in trenches, 13.6 miles tunnel at hydraulic gradient, 33.8 miles tunnel under pressure beneath streams and valleys and the city, and 16.6 miles steel and cast iron pipes. The pipe into Queens from the tunnel terminal in Brooklyn will be 6.6 miles long. Ninety-two miles of the aqueduct are north of the city line. Since the sources of supply are on the west side of the Hudson river but the city on the east, this mighty stream, or, more strictly, tidal estuary, has to be crossed; 47 miles of aqueduct are west of the river.*

An aqueduct 92 miles long, no matter how securely built, may suffer an accidental break; any aqueduct requires cleaning, inspection and repairs. These operations necessitate an interruption in the flow of water, but the community must be supplied uninterruptedly. A duplicate aqueduct would be a very costly way of meeting these occasional needs, at least until demands for more water made a second aqueduct necessary for delivering the usual supply. To provide against such interruptions in the delivery of water, to equalize the hourly and daily fluctuations in its use, and to have a large reserve near the city for insurance against other contingencies, a large distribution and storage reservoir and an equalizing reservoir are included in the scheme.†

Organization.—Organization was the first great problem to be solved, but, as on most important civil engineering enterprises, it has been worked out coincidently with the physical and economical problems of these first years. How great an administrative and engineering force would be required? How should the force be divided and sub-divided for greatest efficiency and

*Other aqueducts are projected for future construction to bring into Ashokan reservoir the waters of the other drainage areas, and additional delivery conduits within the city will be provided to convey the water into the distribution pipe systems in the streets as required. Provision for filtering the water, whenever this may become advisable, has been made. Also an independent source of additional supply, Suffolk county, immediately east of the Ridgewood drainage area, has been investigated. From this territory an excellent ground water could be obtained at reasonable cost.

†For the former, an existing reservoir, known as Lake Kensico, 3 miles north of White Plains, is to be very greatly enlarged, and for the latter a wholly artificial basin is being constructed on the most southerly hilltop of sufficient elevation, Hill View, just north of the city line, in Yonkers.

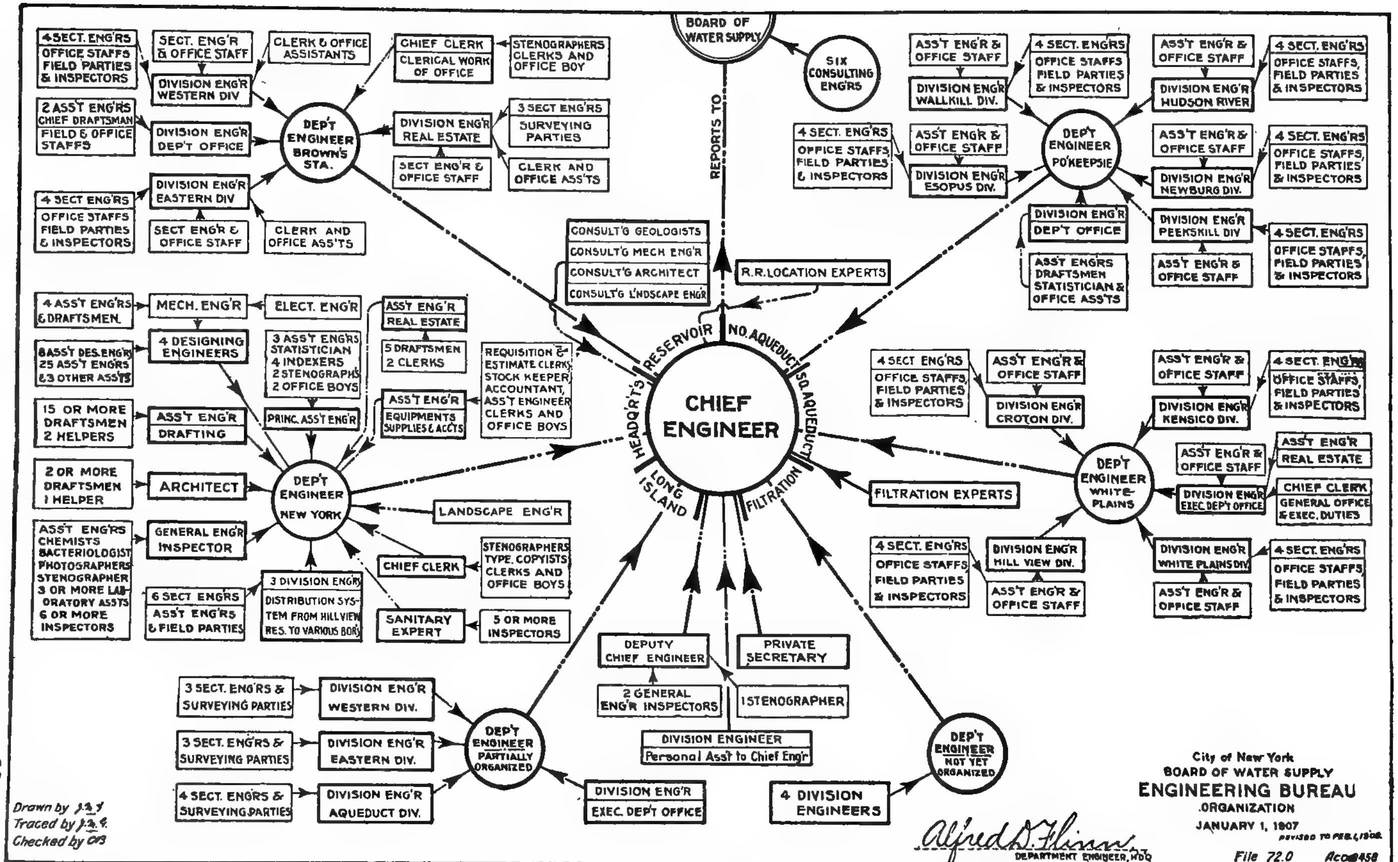

FIG. 16.—PLAN OF ORGANIZATION.

Long Island department was disbanded after completing Suffolk County investigation. City Aqueduct department, to have charge of construction within the city, is to be organized.

proper fixing of responsibility? How should duties in field and office be apportioned? Upon proper answers to these and many similar questions depended the smooth progress of the work. The requirements of Chapter 724 of 1905, creating the Board, that in general work exceeding $1,000 in value should be performed by contract, unless of an exploratory nature, determined in advance one of the large elements of the organization problem.

An administration and an engineering bureau divide the bulk of the Board's work, but there are also a police bureau and a real estate bureau. Heads of bureaus report directly to the Commissioners. In accordance with the Act, the Board consists of three commissioners appointed by the Mayor and removable only for misconduct, on proven charges.*

The secretary is at the head of the Administration Bureau, and the chief engineer is at the head of the Engineering Bureau, which naturally is by far the largest of all. In the Administration Bureau are the auditor, the chief clerk and purchasing agent, the assistant secretaries and paymaster. The Police Bureau meets a requirement of the Act for protection of the communities into which large numbers of laborers would be brought for the performance of the work.†

Physical features of the system and the amount of work which one engineer could efficiently supervise in a general way determined the great divisions of the field work for the Engineering Bureau, each of which was made a department. Likewise, the work in the New York office and surveys within the city limits were made the province of another department. In deciding the number and limits of the field departments, the increased possibilities of supervision due to the automobile and telephone were taken into the reckoning. The saving of one department organization offsets many more automobiles than

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*Mayor McClellan, carrying out an idea which could not be embodied in the law, selected the first commissioners from three lists of three names each, presented by the Chamber of Commerce of the State of New York, the National Board of Fire Underwriters, and the Manufacturers' Association of New York. The Board of Water Supply of the City of New York at present consists of John A. Bensel, president; Charles N. Chadwick and Charles A. Shaw. F. Waldo Smith is chief engineer.

†It is under a Chief Inspector and an Inspector, and numbers 36 sergeants and 185 patrolmen; this force is uniformed, and 51 men are mounted. Buildings for their accommodation have been secured or built at strategic points along or near the line of construction operations.

are required to effect the saving, besides simplifying all administrative and supervisory work.

For the Engineering Bureau, the general scheme of organization is indicated by an accompanying diagram. Work on the watersheds, comprising immediately the surveys and construction connected with the Ashokan reservoir and the headworks of the Catskill aqueduct, was assigned to the Reservoir Department. The sixty miles of aqueduct from Ashokan reservoir to the Croton watershed, including the Hudson river crossing, became the territory of the Northern Aqueduct Department. The remainder of the aqueduct to the city line, together with Kensico and Hill View reservoirs, was apportioned to the Southern Aqueduct Department.

The preparation of designs, specifications, contracts, and real estate maps and documents; executive and civil service matters, and reports; inspection of manufactured materials; many special investigations and other functions affecting the Engineering Bureau as a whole, and the surveys for the delivery tunnels and conduits within the city limits, were assigned to the Headquarters Department. This department includes the physical, chemical and photographic laboratories, and a central storeroom for supplies.*

Surveys, etc., etc.—In making preliminary location studies for the aqueducts and reservoirs, the topographical maps of the United States Geological Survey were of great assistance, and they continue to be useful in many ways during the construction period. In supplementing these and other maps existing at the commencement of its work, the Board has made hundreds of miles of topographical and property surveys and level circuits. For topographical surveys the stadia method has been used almost exclusively. All surveys have been based upon triangulation and reduced to a co-ordinate system connected with government triangulation stations. Leveling, including bench levels, has been done almost wholly with dumpy levels, securing very satisfactory precision and great economy. Surveys and borings

*The City Aqueduct division, it is intended, will be erected into a department when active construction commences. Long Island and filtration departments were projected for carrying on those parts of the system whenever undertaken. Indeed, the former was partially organized, and made the exhaustive studies and surveys forming the basis of the city's application to the State Water Supply Commission for the waters of Suffolk county. Each department is divided into a few divisions and these are sub-divided into sections.

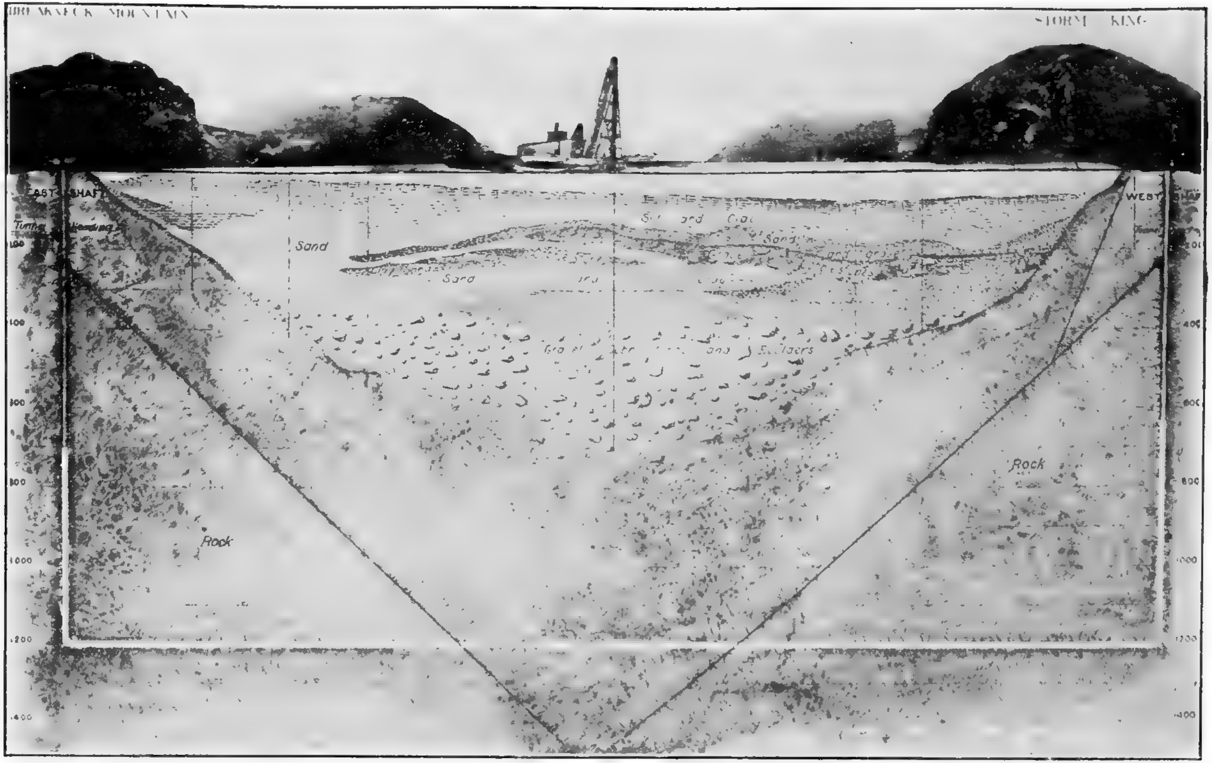

FIG. 17.—HUDSON RIVER CROSSING.

Composite of the profile and panoramic photograph showing vertical and completed inclined borings to and in rock (April 6, 1910). The long inclined borings cross 1500 feet below river surface. Since the illustration was made two similar borings have been driven from same points and crossed 960 feet below middle of river. The vertical hole under the drill scow has reached a depth of 751 feet (Oct. 1, 1910).

for the Ashokan reservoir have been described in detail in a separate interesting paper.*

Sub-Surface Investigations: *Borings*.—Sub-surface information is as essential to the location, design and construction of works like those of the Catskill water supply as is topography. Therefore, many wash and core borings, soundings and test pits have been sunk all along the line, especially at dam sites and tunnels, where accurate knowledge must be had not only of the depth to rock but of the character of the rock and of the materials overlying it. For the pressure tunnels, the rock had to be explored to great depth at many places. Thousands of holes have been made, aggregating many miles in length and costing hundreds of thousands of dollars, but the economy in safety of location, and in cost and time of construction resulting through more accurate designs and specifications, and more intelligent bidding, far outweigh the investment in exploration.

Spacing and depths of borings have been varied according to the purpose of the exploration and the local geology. Cores and other samples obtained have been carefully preserved and full records filed. The geologists have studied the results as obtained, and have advised about the locations of many holes. Several pre-glacial gorges have had to be located; faults, contacts and other features of rock structure determined. Incidentally, geological knowledge of the State, from the heart of the Catskills to Staten Island, has been greatly enriched.†

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*By Division Engineer J. S. Langthorn, before the Brooklyn Engineers' Club, January, 1908, and in a book entitled: "Preliminary Work on Ashokan Reservoir," recently published. To secure the best sites for the dams and the most economical location for the aqueduct, many alternative locations were reconnoitered and surveyed, and many comparative estimates of cost and construction time made.

†While boring for the Ashokan dams, the existence of a pre-glacial gorge near the bed of a small stream, the Beaverkill, was suspected by one of the geologists. Borings at intervals of approximately 100 feet had been made across the place, but all proved rock at high levels; then the geologist indicated one of the spaces in which he desired an intermediate hole; here the drill went down about 100 feet deeper, and a few more holes outlined a narrow gorge in the rock, with porous gravel at the bottom. Subsequent excavations for the core wall of the Beaverkill dikes exposed the gorge exactly as predicted.

Crossing the Hudson, however, has required the most difficult, interesting and protracted boring of all. First, several river cross-sections were investigated with wash borings made from scows, but it soon became evident that such borings did not reach ledge rock, being stopped by boulders. Diamond drills were early employed, and not only the main stream but the important tributaries on both sides were explored from New Hamburg to Stony Point, the geologists meanwhile studying the regional geology, in a broad way, for miles on either side of the river and up and down the stream. Finally, the northerly gate of the Highlands was chosen as the best location, considering not only the river gorge, but the approaches on both banks. Here sound granite, the granite used for building High Bridge to carry Croton aqueduct across the Harlem river, outcrops in the two picturesque emi-

Ashokan Reservoir.—Partial conception of the far-reaching consequences of the creation of a great artificial lake like Ashokan reservoir can be gained from a few statistics of the changes to be wrought: Seven villages, comprising some old settlements, with all their traditions, will be erased from the map; from 40 private and public cemeteries, 2,500 bodies are being removed for reinterment; the Ulster & Delaware railroad's tracks, which traverse the full length of the basin, will have to be relocated. Likewise, 64 miles of highway will be abandoned, and new and better highways, with permanent masonry bridges, constructed around the reservoir. One bridge, 1,270 feet long, will cross the middle of the reservoir over the dividing weir. Improved forests will surround the new lake, and within comparatively

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nences, Storm King and Breakneck mountains, and was predicted to continue uninterruptedly beneath the river.

Since the summer of 1906, vertical borings from scows have been in progress. This has proven one of the most difficult undertakings of its kind. Strong winds, tides and currents, and a heavy river traffic have greatly augmented the troubles attendant upon drilling through 50 to 90 feet of water and penetrating hundreds of feet of silt, sand, gravel and bowlders before reaching ledge rock. Winter, with its ice and severe storms, has enforced a cessation of work for several months each year. Eleven vertical holes have been sunk from the river surface, and one is in progress at the middle of the river at a depth of 710 feet. Several holes were lost through accident just as they were attaining an interesting depth.

An inclined diamond-drill hole, starting in the rock outcrop, close to the water's edge, was bored in each bank of the river to a depth of 275 feet, and 566 feet on the easterly and westerly sides, respectively; these holes showed the rock to be sound throughout their length.

To more thoroughly explore the rock beneath the river, it was finally decided to sink a test shaft on each shore, which, if successful, might become part of the permanent works; and from chambers in these shafts to drive inclined diamond-drill holes until they should cross under the middle of the river. The east shaft has reached a depth of 816 feet and the west shaft 755 feet. At a depth of about 300 feet, the drill chambers were blasted out of the solid rock. The first pair of drill holes was started June 1, 1909, and August 4, 1909, and completed February 9, 1910, and March 31, 1910, on the east and west sides, respectively. Their average inclination approximates 40 degrees from the horizontal. The easterly hole is 1,834 feet long and the westerly 2052 feet. The distance between shafts is 3030 feet, and the holes crossed at a vertical depth of about 1500 feet below the river surface. A piece of core 8 feet long was recovered from the east hole 1451 feet from the chamber, proving not only the excellent character of the rock but the straightness of the hole. Both holes were in sound rock throughout. The holes were 2⅝ inches in diameter at the beginning and 1½ inches at the end. Two other similar holes were started in April, 1910, with the intention of having them pass at a depth of about 1050 feet vertically below the middle of the river. The east hole of this pair is now about 521 feet and the west hole 216 feet long. No more water has been encountered in the shafts and drill holes than can readily be handled by usual methods. Some of this was evidently fossil water, being of entirely different chemical composition from the river water and containing several mineral elements in much higher proportion than sea water. Several instructive articles on this work have been published in the *Engineering Record* and *Engineering News*. Present expectations are that the tunnel can be driven at a depth not lower than 1200 feet horizontally across the river. August 31, 1910, the hole in the middle of the river had reached a depth of 750 feet. The east shaft was about 1025 feet deep October 1, and the west shaft 925 feet. Each hole of the second set drilled from the shafts was inclined 24 degrees from the horizontal. The east hole was finished August 5, with a length of 1651 feet, and the west hole August 25, with a length of 1652 feet; they passed at a depth of 960 feet below river surface. When finished, the east hole was yielding 105 gallons of water per minute and the west hole only 25 gallons.

few years the reservoir will become one of the notably beautiful features of a beautiful region.

Kensico Reservoir.—Kensico reservoir will be formed by building a great masonry dam across Bronx river valley, just upstream from the existing small earth dam; this new dam will be 1,830 feet long and have a maximum hight above the lowest foundation of nearly 300 feet. One of the illustrations shows

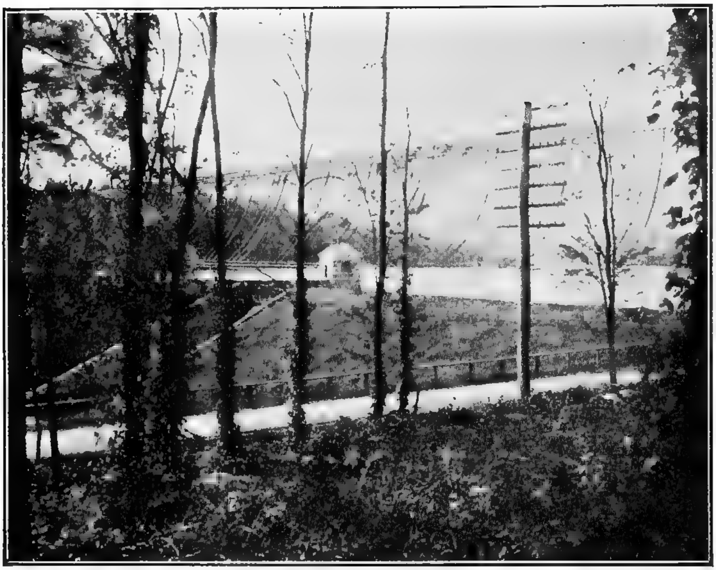


FIG. 18.—VIEW OF THE SPILLWAY AND DAM OF THE PRESENT KENSICO RESERVOIR.

(Courtesy of The Century Co.)

In shadowy outline the proposed new dam has been drawn on the photograph. It will be on the average 400 feet north of the old dam and its parapet will stand as here shown 125 feet above the water-level seen in the photograph, a greater hight of dam (about 175 feet) extending beneath this water-level. Steps will ascend both hillsides. The present State road is shown in the foreground. The old dam is to be removed.

a cross-section of Olive Bridge dam at Ashokan reservoir, and this dam will be similar. An earth dike, 1,500 feet long, with a maximum hight of 30 feet, is being built to fill a depression in the rim of the basin about one mile northwest from the main dam. Kensico reservoir occupies two branching valleys, and is of quite irregular shape. Its greatest length is 4 miles, and its shore line will measure 31 miles. Its total capacity is approximately 40,000,000,000 gallons, of which 20,000,000,000 are

available for direct draft through the aqueduct. In emergency, a large portion of the remainder can be obtained by a temporary pumping plant delivering into the aqueduct at one of the gate-houses. When full, the water surface of this reservoir will be 355 feet above tide and of 3.5 square miles area.

This beautiful lake, with its structures situated close to the four-track Harlem division of the New York Central railroad and within easy automobile distance of New York City, will be the most conspicuous single feature of the system, and therefore careful thought has been given to the æsthetic elements in the design, as well as to the utilitarian. Catskill aqueduct enters this reservoir near the northerly end of the westerly arm, and draws water from the reservoir on its westerly side, about one mile northwest of the main dam. Between the inlet and outlet gate-houses a by-pass aqueduct is being constructed, so that water can be carried around the reservoir before it is completed, or at any other time when this may be desirable in the future.

Hill View Reservoir.—Hill View reservoir is being made by digging an artificial basin in the broad, flat hilltop, and utilizing the excavated materials to form embankments which will increase the depth of the reservoir.*

A concrete wall divides the reservoir into two basins, and in this wall is formed a conduit through which water can be sent by the reservoir directly to the city without entering either basin. Opportunity is thus afforded for delivering water to the city before the reservoir is completed, or for maintaining the delivery of water when both basins are emptied for cleaning or repairs.

Design of Masonry Dams.—In designing the great Olive Bridge and Kensico masonry dams, consideration was given to every conceivable force which might affect their stability, permanence and water-tightness. Not only were recognized formulas for determining the cross-section applied, but new analytical and graphical methods were devised under the direction of the writer, and, finally, careful comparisons were made with a great many existing dams, data concerning which were

*Its capacity will be 930,000,000 gallons; length, 3000 feet; width, 1000 feet; depth of water, 36 feet. The water surface will be 295 feet above tide. The bottom and sides of the reservoir will be lined with concrete up to about elevation 280, above which stone paving will be used. It is being constructed as an open reservoir, but so designed that a groined arch concrete roof or other suitable covering can be added, if ever found desirable.

collected to supplement the large body of such information gotten together in connection with the Wachusett dam of the Massachusetts Metropolitan Water Works.

The common defects of high masonry dams, which are disfiguring and may, ultimately, have serious consequences, are cracks caused by temperature changes and seepage of water caused by pressure, with accompanying efflorescence of lime and magnesium salts on the downstream face of the dam.*

Owing to its conspicuous location, it is intended to give Kensico dam a dignified and worthy architectural treatment, with aspirations for a result more pleasing than the structures sometimes built by engineers without competent advice on æsthetic subjects.

Masonry Dam Construction.—Of first importance in constructing a masonry dam is the securing of solid rock foundation and the preventing of the passage of water through the rock beneath the dam under the pressure that is to be after the filling of the reservoir. Having removed the earth and the unsound and loose rock, a cut-off trench is excavated in the rock, approximately parallel to the axis of the dam and generally near the upstream side, deep enough to interrupt any seams or crevices, and filled with masonry. In addition, holes are often drilled into the rock at various points throughout the foundation area, and grout of cement or of a cement and sand is pumped in under pressure, in order to fill any crevices or other voids under the dam. Scrupu-

*To provide for the temperature change movements and thus control the cracking, transverse expansion joints are being constructed in the dams at intervals of about 80 feet, extending from near the foundation through the top. These joints are so formed that the very slight movements necessary can occur without opening a free, continuous water passage through the masonry. Furthermore, near the upstream end of each joint a well is being formed from bottom to top of the dam, which, after the first adjustments have naturally taken place, can be filled in such a way as to make a positive water-stop across the joint. In large masses of concrete masonry, during the process of setting, much heat is generated by the chemical action of the cement, thus raising the temperature far above that of even summer atmosphere. Consequently, the first range of temperature as the masonry cools is greater than the subsequent ordinary variations.

To prevent, or at any rate minimize, seepage, the upstream faces of the dam are being built of large and very dense concrete blocks, and all reasonable precautions are being exercised to render the whole mass of the dam highly impervious. Recognizing that this first defense may prove vulnerable to some slight degree, a system of drains is being built in each dam near its upstream face, in order to intercept any seepage water and conduct it away harmlessly instead of permitting it to pass on to the downstream face of the masonry. These drains are nearly vertical, 16 inches in diameter, 12 feet from the water face of the dam at their tops and 12 feet apart, opening at top and bottom into a gallery large enough for men to enter. From the lower gallery a conduit will convey the collected seepage, if any, to a convenient place downstream from the dam. The drains are formed by laying up along with the other masonry concrete blocks 3 feet in each dimension and made as pervious as feasible—concrete sponges. The intention is to make it easier for any water penetrating the upstream face of the dam to enter the drains than to go by them.

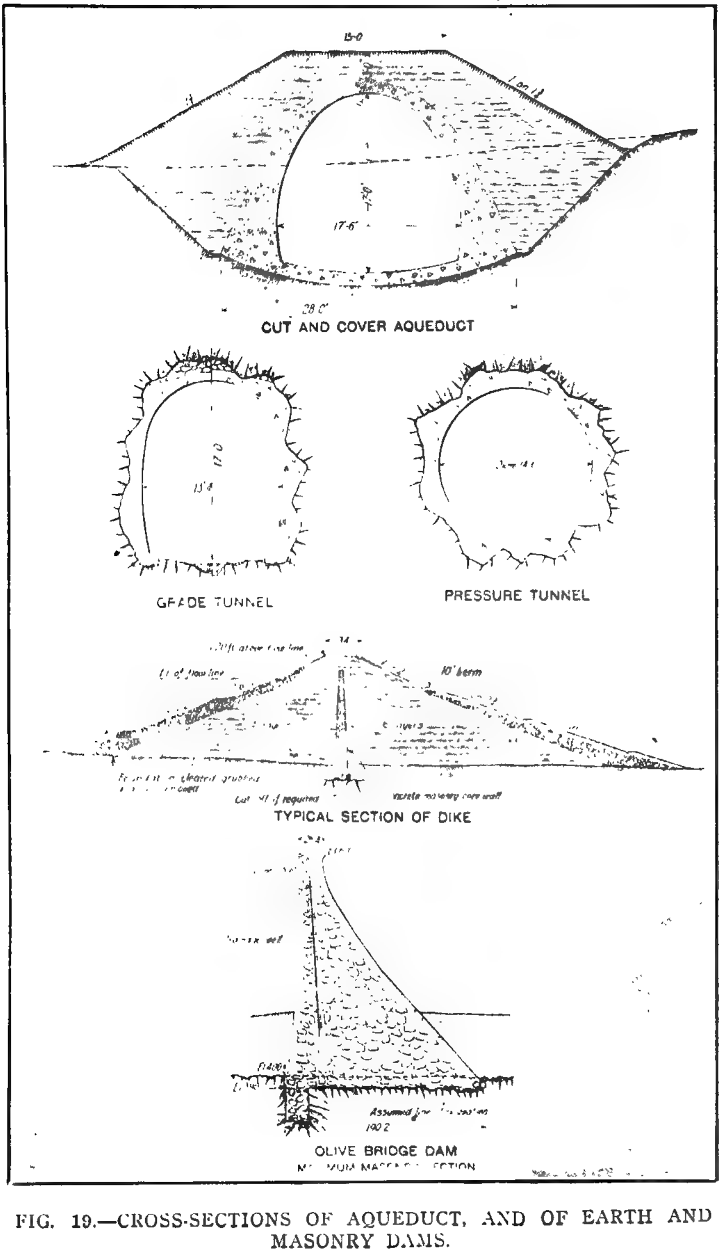


FIG. 19.—CROSS-SECTIONS OF AQUEDUCT, AND OF EARTH AND MASONRY DAMS.

lous cleaning of the rock surface is insisted upon, and the masonry is begun with a layer of rich mortar on this clean surface.

Cyclopean masonry in the heart of the dam is built by depositing large batches of semi-liquid concrete, and lowering into this concrete, immediately, large, irregular-shaped, clean, sound stones. Spaces between large stones are filled with concrete and smaller stones. The concrete block or cut stone facing of the dam is built a course in advance of the cyclopean masonry, to serve as forms. Concrete blocks for facing, for expansion joints and for drains are cast several months before they will be needed, to allow sufficient hardening. Springs of water encountered in the foundation are taken into small iron pipes, which are built up in the masonry until the pressure is balanced. At a suitable time each such pipe is grouted under pressure and capped.*

Earth Dams.—Earth dams, or dikes, or embankments, are being used very extensively at Ashokan and Hill View reservoirs, because of their economy and other advantages. Fortunately, local materials of unusual excellence for this purpose are abundant and of such character as to make very impervious embankments.†

Foundations are prepared by carefully excavating all vegetable soil and grubbing out roots, so that a union can be secured between compact, impervious earth and the first layers of the dam.

Catskill Aqueduct.—Design.—Catskill aqueduct was designed to have an effective capacity of not less than 500,000,000 gallons daily throughout the year. Hence, it will be large enough

*The record rate of laying masonry in any one dam was made October, 1909, at the Olive Bridge dam, when 35,300 cubic yards were placed in one month. A large and costly construction plant, totaling hundreds of thousands of dollars, is required for construction operations of such magnitude as the principal dams of the Catskill waterworks.

†At Hill View reservoir no core walls are deemed necessary, because the banks are of great thickness, in order to dispose of the materials excavated in forming the reservoir. At Ashokan, concrete core walls are being used, except in the dividing dike. On the water side of core walls, the bulk of the earth, free from large stones, is spread in layers, which, when very thoroughly compacted, are 4 inches thick; elsewhere, embankment layers are usually 6 inches thick after being compacted. Water slopes are protected by thick layers of stone riprap and paving. Downstream slopes are provided with internal drainage, and, together with the tops, will be covered with soil, and grassed. Long slopes are broken by berms at intervals of 30 feet vertically, and high embankments have flatter slopes toward the bottom.

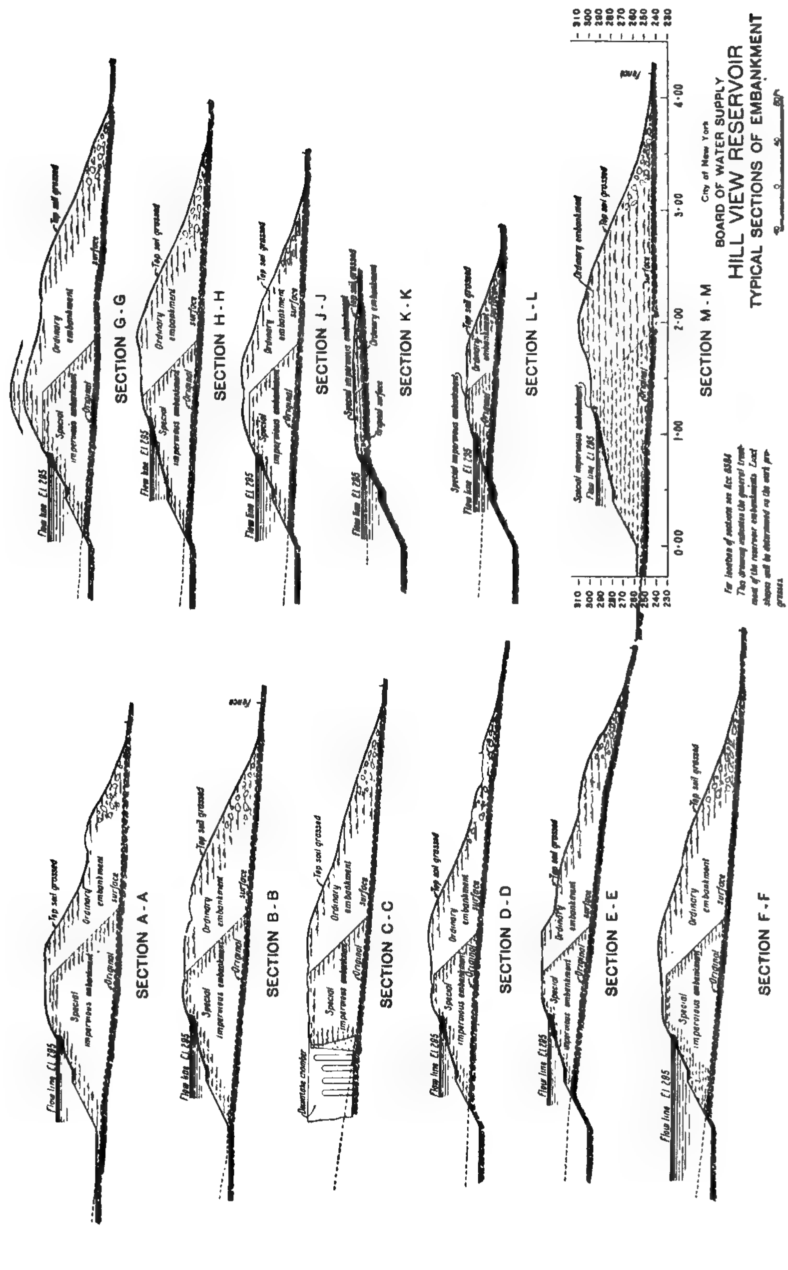


FIG. 20.—EARTH DAMS.

to bring to New York water from the next watersheds to be developed after the Esopus.*

An "aqueduct," broadly defined from the derivation of the word, is any large, artificial, covered channel for "leading water." Owing to topographical and geological conditions, the Catskill aqueduct is made up of several distinctly different types of conduit: cut-and-cover or open-cut aqueduct, grade tunnels, pressure tunnels, reinforced concrete conduits, steel pipes protected by concrete, plain steel pipes and cast-iron pipes.†

The aqueduct in dry, loose earth was designed to withstand the weight of the embankment about it, whether full of water or empty; also to withstand the water pressure when full without the aid of the surrounding embankment; it was designed to withstand the pressure due to the water rising, from some unusual condition, above the inside top of the arch. With the regular 3-foot embankment over the top of the arch, the cut-and-cover sections are safe to carry a 12-ton road roller, a condition that may occur at road crossings. Or it is strong enough to support earth to a depth of 14 feet over the top of the arch. For fills greater than this, reinforcement of steel rods is placed in the invert to enable it to withstand the reaction caused by the heavy load. In cases where a wet earth foundation is encountered, the aqueduct is constructed on a timber platform arranged to allow the ground water to drain to sumps without washing away the mortar from the freshly laid concrete. Wherever the level of the ground-water adjacent to the aqueduct is higher than 9 feet above the invert, the latter is made thicker, in order to withstand the upward hydrostatic pressure when the aqueduct is empty.

An aqueduct built in trench is of two kinds: cut-and-cover aqueduct, following the hydraulic gradient and of the shapes

*Thorough investigations show this policy to be more economical and in other ways preferable to building now an aqueduct only large enough for the Esopus water and later other aqueducts for each increment of supply.

†The first is the least expensive and is adopted wherever the topography affords support at the hydraulic gradient, but mountains and valleys interrupt such a line and detours around them would be impracticable. Mountains and hills are pierced by tunnels at the hydraulic gradient. Broad, deep valleys underlaid with suitable rock are crossed by pressure tunnels driven deep in the solid rock. For crossing minor valleys, steel pipes protected with concrete are employed; and for depressions not more than 50 feet below the hydraulic gradient, reinforced concrete conduits. Within the city limits, for connections with the distribution pipes and for the pipe lines extending from the terminal of the tunnel in Brooklyn, steel and cast-iron pipes will be laid.

shown typically in the illustrations; and reinforced concrete conduit.*

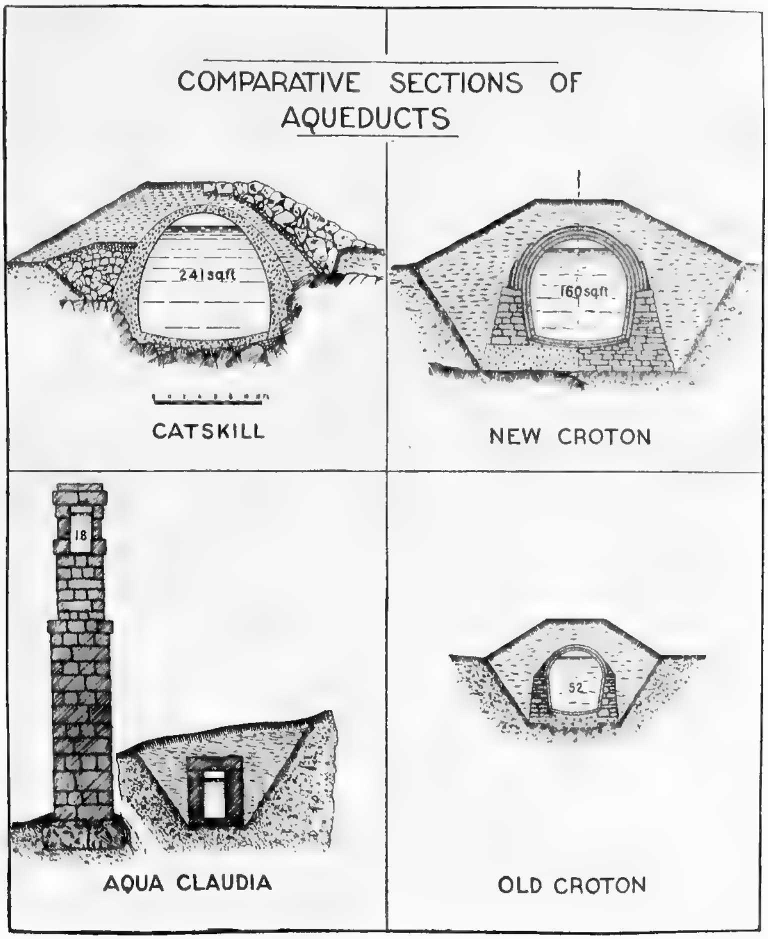


FIG. 21.—COMPARATIVE SECTIONS, DRAWN TO SCALE, OF CROTON, NEW CROTON AND CATSKILL AQUEDUCTS AND OF AQUA CLAUDIA.

*Between Ashokan reservoir and the filter site, the cut-and-cover aqueduct is 17 feet high and 17 feet 6 inches wide inside and slopes .00021 foot per foot. Between the filter site and Hill View reservoir, aqueduct of this type is 17 feet 6 inches high by 18 feet wide and slopes .000182 foot per foot. Its interior is uniform in shape, but the exterior is varied to suit the material in which the trench is excavated—ordinary loose earth, compact earth, rock, and combinations of rock with earth. Only a very small proportion of the aqueduct's length is on embankment, totaling about 9000 feet. Such foundation embankments are used only for crossing very small depressions which could be avoided only at large expense.

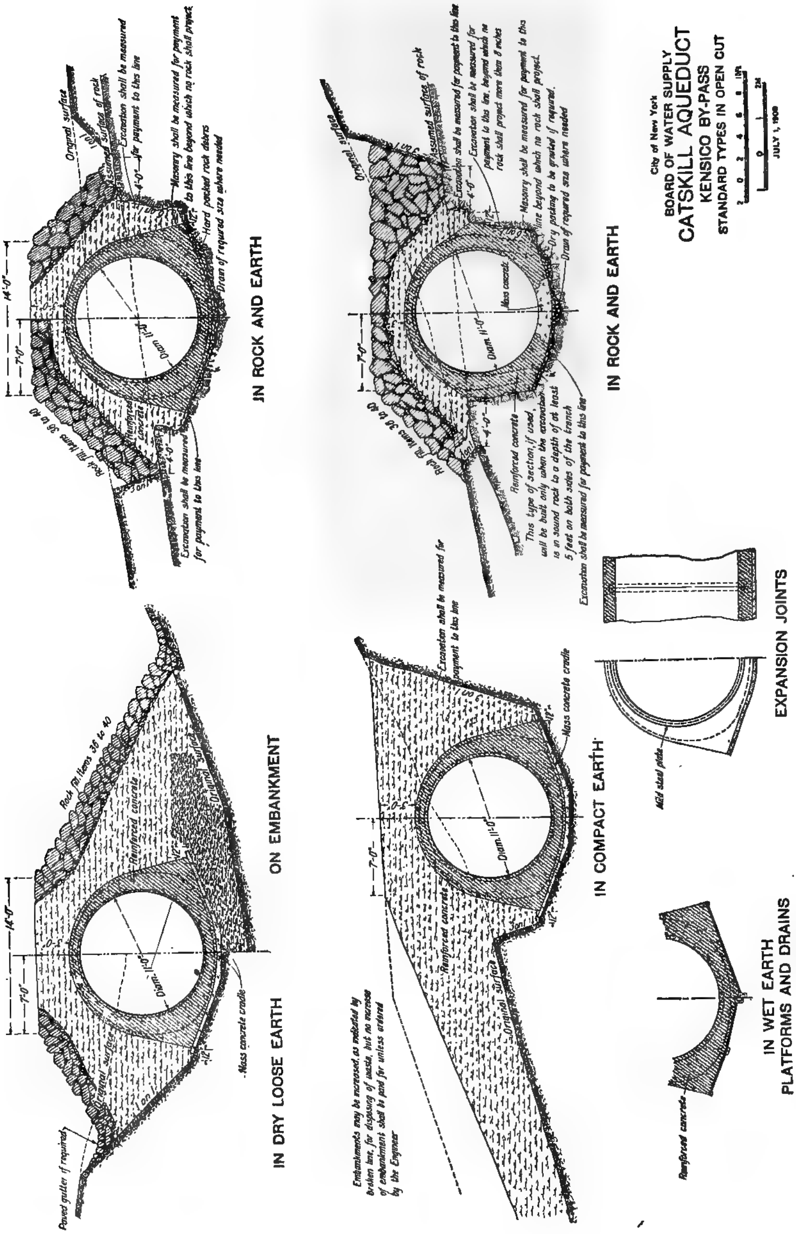


FIG. 22.—STANDARD TYPES OF REINFORCED CONCRETE AQUEDUCT LAID IN OPEN CUTS.

Streams and other drainage waters are carried beneath the aqueduct in substantial concrete culverts of liberal capacity, excepting that in a very few places where the aqueduct is in deep trench, peculiar local conditions make overhead culverts more convenient and permissibly safe. Culverts and foundation embankments are constructed in advance.

Aqueduct Construction.—Quite generally steam shovels are being used to excavate the greater part of the materials from the aqueduct trench, trimming to exact shape being done by hand

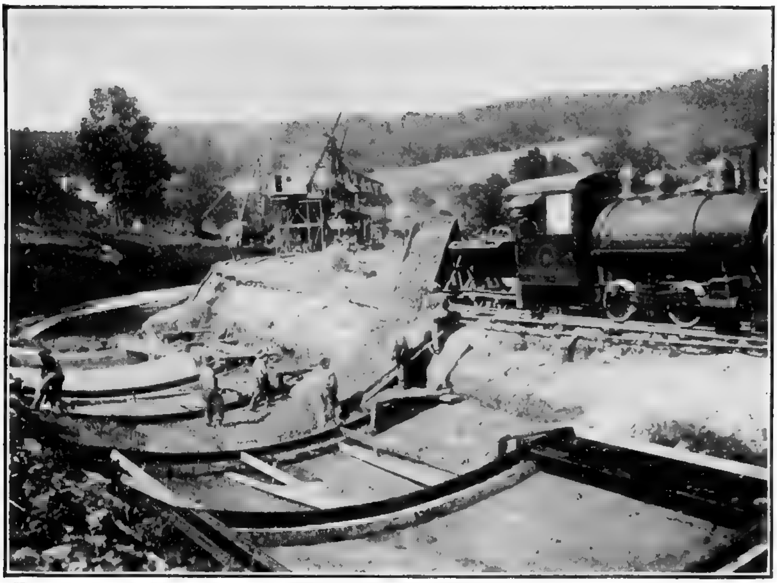


FIG. 23.—CUT-AND-COVER AQUEDUCT, SHOWING METHOD OF LAYING INVERT; KEY BLOCKS IN FOREGROUND.

just before the placing of the first concrete. The invert, or floor, is placed first in sections 15 feet long with a concrete key block under each joint where sections butt. Each section of invert is screeded to shape between end guide-boards with a wooden straight-edge, or by rolling with a length of 3-inch or 4-inch diameter steel shafting or pipe.

Usually the sidewalls and arch are built monolithic in one operation. Sections from 15 feet to 75 feet long are permitted, the condition being that in any such section the concrete shall

be placed continuously with no interruption exceeding 15 minutes. Laying the two sidewalls to a hight not greater than 8 feet above the lowest part of the invert as a second operation, and completing the arch as a third operation, are also permitted. Some of the reproduced photographs show these several steps of aqueduct construction. Expansion joints are formed in the ends of abutting sections of the sidewalls. Of these joints,

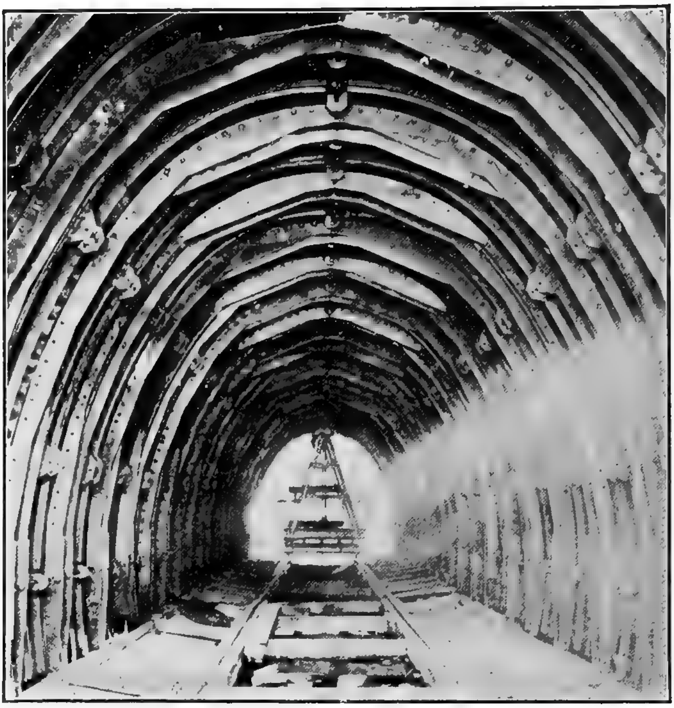


FIG. 24.—CUT-AND-COVER AQUEDUCT (CATSKILL), SHOWING INTERIOR OF STEEL FORMS FOR CONCRETE CAR FOR MOVING FORMS IN BACKGROUND.

some have tongues and grooves formed in the concrete, and others bands of ¼-inch by 4-inch flat steel embedded part of their width in one section and part in the other.

Steel forms are used for the inside of the aqueduct, and give the concrete a very smooth surface. After the concrete has attained sufficient strength, stretches of the aqueduct about 200 feet long are tested by filling with water between bulkheads. So far

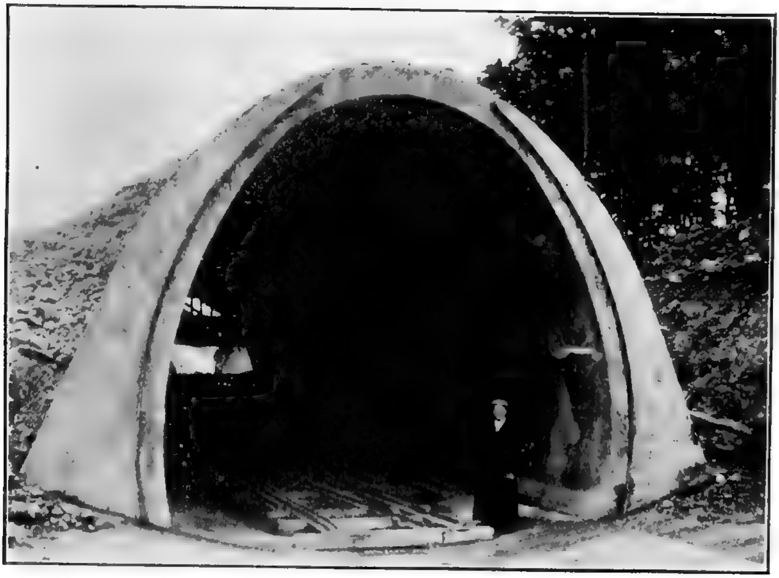


FIG. 25.—CATSKILL AQUEDUCT, COMPLETED PORTION; MAN (HIGHT 5 FEET 8½ INCHES) STANDING AT BASE, SHOWING COMPARATIVE SIZE.

FIG. 26.—GENERAL VIEW OF A SECTION OF THE CATSKILL AQUEDUCT.

these tests have shown the concrete to be satisfactorily water-tight.

Tunnel Design and Construction.—Tunnels, being more costly than cut-and-cover aqueduct, have for economy been made of smaller cross section; and, consequently, in order that they should have the same capacity, they have been given steeper slopes, to-wit: .00037 north of the filter site and .00032 south. To prevent air pockets in the aqueduct roof, grade tunnels have been given the same hight as the adjacent cut-and-cover, but reduced widths, respectively, 13 feet 4 inches and 13 feet 9 inches.

Pressure, or siphon, tunnels, being still more costly, have been given still smaller cross sections and steeper *hydraulic* slopes. Actual slopes of pressure tunnels, however, were determined by convenience of driving, and of drainage during construction and subsequently. The hydraulic slopes above and below the filter site are, respectively, .00059 and .000313. Naturally, pressure tunnels are circular in section, their diameters ranging from 11 feet to 16 feet 7 inches, according to the economic distribution of the head or fall. For safety and economy of construction, and for permanence, these tunnels are located deep in solid rock. At least 150 feet of rock are required over the tunnel, no matter how deep the earth above, excepting that a somewhat less rock cover was deemed sufficient for the tunnel just north of Hill View reservoir, where the pressure is slight.

The chief dependence for water-tightness in pressure tunnels is the rock. But to increase its resistance to leakage, very thorough grouting, under high pressure, will be done after the concrete lining is well set, the lining being designed of sufficient strength for this purpose. Pipes for the grouting are set in advance of the lining, places where water enters the tunnel being marked as discovered during excavation.

Circular shafts are needed for waterways at each end of each siphon tunnel connecting the tunnel with the aqueduct at grade. At an intermediate position on each tunnel a circular drainage shaft is also provided. The designing engineers were of opinion that circular shafts could be sunk more expeditiously and economically than rectangular shafts of the usual dimensions. American contractors have preferred the latter; but the former

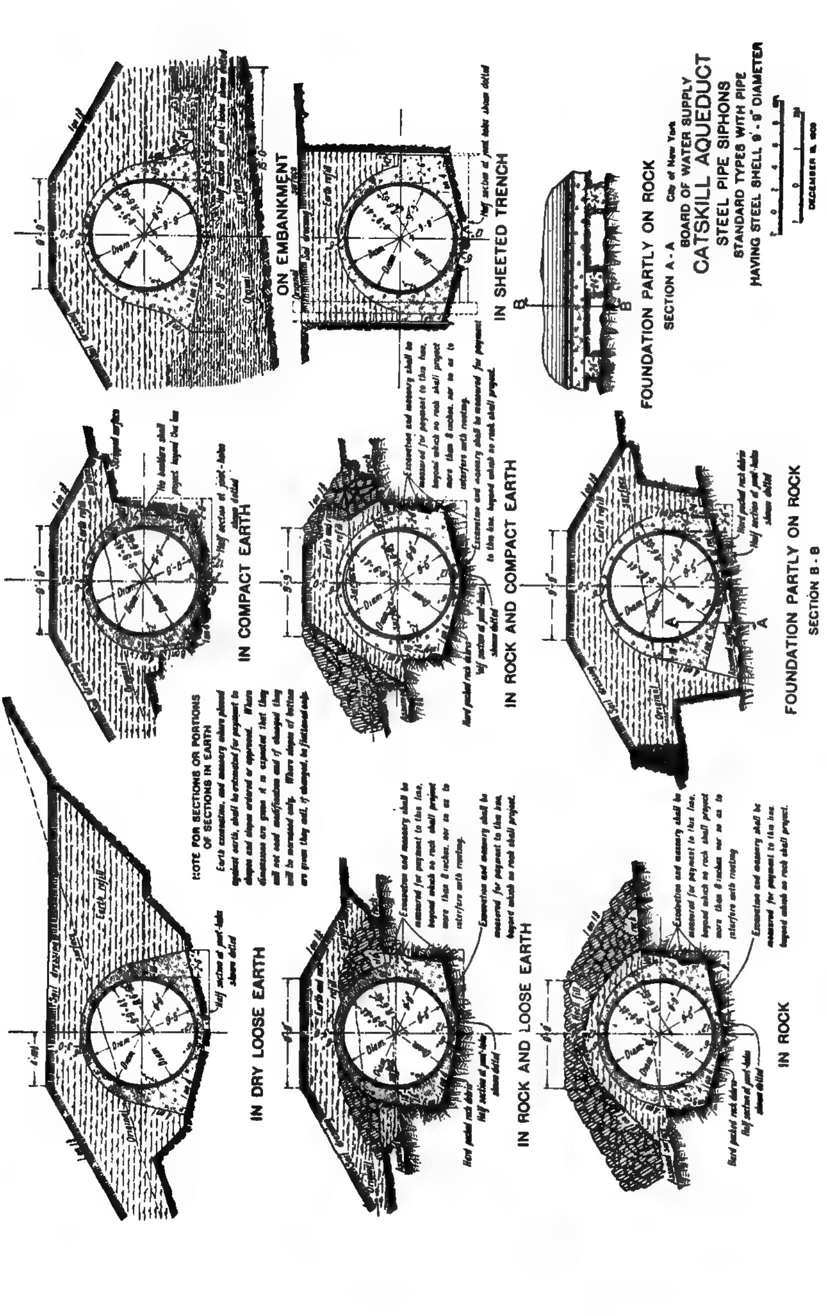
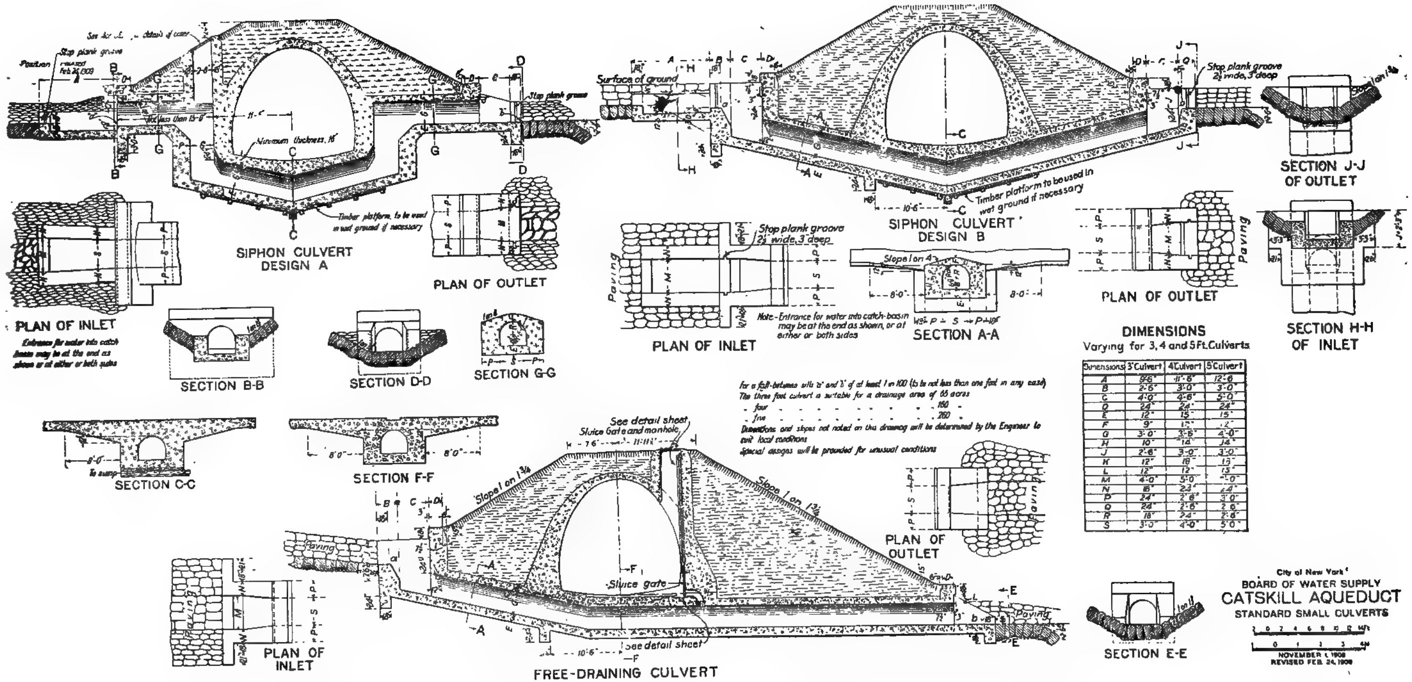


FIG. 27.—STEEL PIPE SIPHONS.

These parallel pipes are required in each siphon for the full capacity of Catskill aqueduct; only one is being laid now, however.



Dimensions	3' Culvert	4' Culvert	5' Culvert
A	9'-6"	11'-6"	12'-6"
B	2'-6"	3'-0"	3'-0"
C	4'-0"	4'-6"	5'-0"
D	24"	24"	24"
E	12"	15"	15"
F	9"	12"	12"
G	3'-0"	3'-6"	4'-0"
H	10"	14"	14"
J	2'-6"	3'-0"	3'-0"
K	12"	18"	18"
L	12"	12"	15"
M	4'-0"	5'-0"	[illegible]
N	18"	23"	24"
P	24"	2'-6"	3'-0"
Q	24"	2'-6"	2'-6"
R	18"	24"	2'-6"
S	3'-0"	4'-0"	5'-0"

FIG. 28.—STANDARD SMALL CULVERTS BENEATH CATSKILL AQUEDUCT.

is European practice. Experience seems to have proved the advantages of the circular shafts, at least for some cases.*

Steel roof support has been substituted for timber in the pressure tunnels. The dry packing outside of roof support in pressure tunnels is grouted so as to make a solid mass.

City Aqueduct.—South of the city line, the portion of the aqueduct which will deliver the water from Hill View reservoir to the several boroughs has been named City aqueduct. At first thought, pipes of cast iron or rolled steel seem obvious means for delivering the water, but when one considers that sixteen 66-inch, or, as a more practical size, thirty 48-inch pipes, would be needed; that New York City's streets are already much occupied by pipes, sewers, subways and other sub-surface structures, especially the north and south avenues in Manhattan, and that still further demands will be made for additional pipes and subways; that traffic is heavy, and that digging trenches for many miles of large mains would be an intolerable nuisance, he is soon convinced that some other means to this end are to be desired.

A pressure tunnel, deep in the rock, has been decided upon. With the immense quantities of water to be conveyed, this type of conduit is much more economical. Pipes would have comparatively short life and are somewhat liable to breaks. With pipes of the necessary size, and under the pressures which will obtain, a break would be disastrous. Masonry-lined tunnels in rock are permanent and secure. No interference with streets will be necessary for tunnel construction, excepting at a very few shaft sites. The tunnel will be at such great depths, ranging from about 200 to 700 feet, that its construction cannot endanger buildings or cause serious annoyance. Shafts will be spaced about 4,000 feet apart, on the average, and for most of them convenient sites in public lands have been found. The tunnel will follow streets, hence only a few small parcels of real estate need be purchased. At the head of each shaft connections will be made to the distribution pipes, construction of the most permanent and massive character being employed. When the

*Records for shaft-sinking in hard rock have twice been beaten on this work, and both times in circular shafts. The record now stands for unlined shaft, 177 feet sunk between depths of 365 and 542 feet below the surface in one working month.

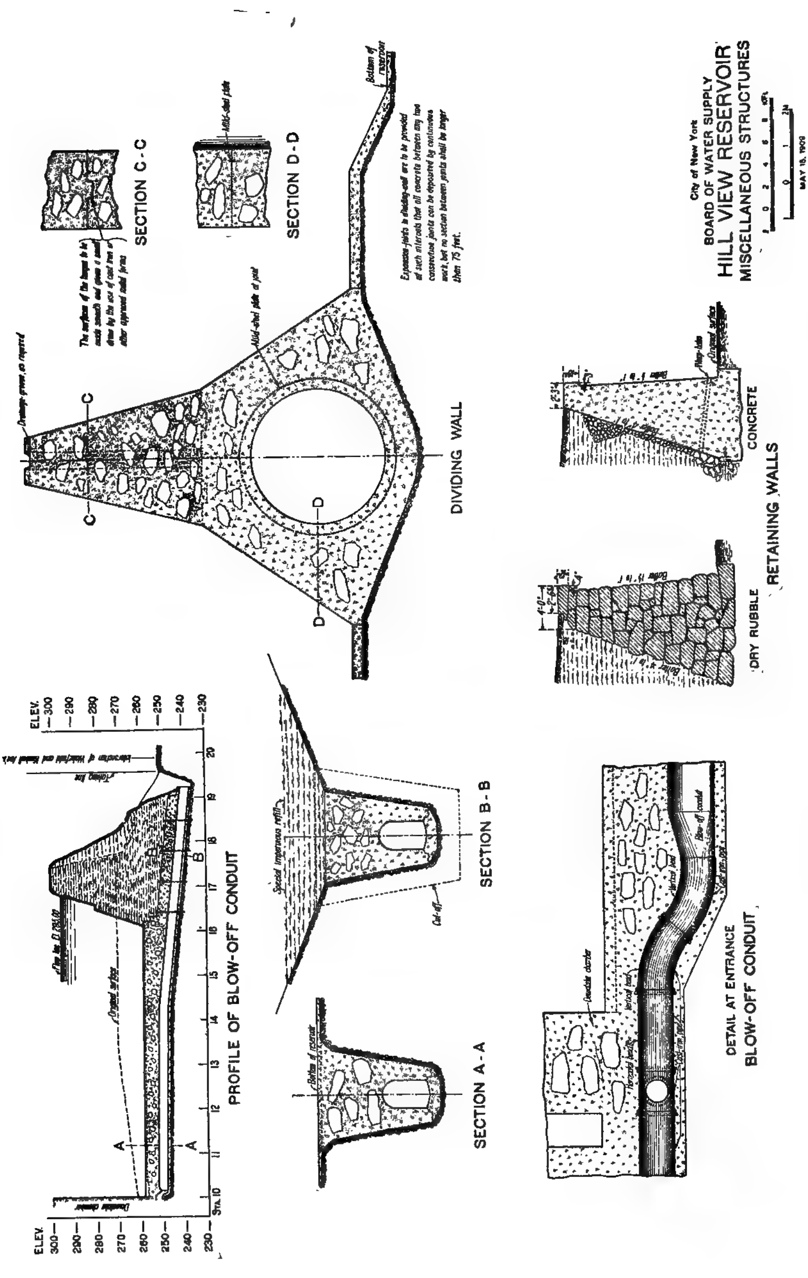


FIG. 29.—MISCELLANEOUS STRUCTURES, HILL VIEW RESERVOIR, SHOWING BY-PASS AQUEDUCT IN DIVIDING WALL.

tunnel is completed, the only visible indication of its existence will be small covers in the surface of the ground over the valve chambers, at the tops of the shafts.

Thorough exploration with drills has proved the feasibility of such a tunnel. Three valleys, or gorges in the solid rock, have been discovered. With suitable street pipes and plumbing, water should rise to the 18th or 20th story in lower Manhattan, and to approximately the same hight as the high service in Brooklyn. A great deal of public and private service pumping can thus be dispensed with, securing noteworthy economy. Better fire protection will also be afforded.

General Considerations in Design.—Permanence has been a paramount desideratum in the design of all important parts of the system. Materials, dimensions, forms and methods have been influenced thereby. Effects of heat, frost, erosion, seismic disturbance, corrosion, and the other destructive actions of nature have been reckoned with, and the difficulties of many an engineering problem have been increased in consequence; but nothing short of the most enduring and secure could be permitted. Several tried engineering constructions have been pushed to advanced applications, as in the pressure tunnels. Some novel solutions of other problems have been made, as in the combination of expansion joints with drainage systems in the masonry dams, and in the method for protecting steel pipes, as well as in numerous details.

Concrete, for reasons of economy, adaptability and permanence, has been selected as the masonry material for practically all parts of the works. Notable likely exceptions are the superstructures of gate-houses and similar buildings and the exposed facing of the Kensico dam. For these structures stone is the preferred material. Concrete is used for the lining of tunnels and for jacketing and lining of steel pipes of the aqueduct; for dams, bridges and culverts; for core-walls in dikes, and for all substructures of buildings. With concrete, a much smoother interior, and, therefore, a larger capacity for a given size, is possible for the aqueduct than if brick or stone masonry were used; superior watertightness is secured for the aqueduct and dams; local materials can be utilized which would not be suitable for other kinds of masonry. This latter is a very weighty

consideration for works stretching a hundred miles or so across country of varying geological formation, large parts of which are not conveniently accessible to railroads and other lines of transportation.*

"Waterproofing" Concrete.

One problem which has been the subject of extensive study and experimentation is that of waterproofing. It is of the highest importance that the relatively thin walls of the cut-and-cover aqueduct, particularly of the reinforced concrete conduits subject to considerable pressure, should not permit the loss of water by leakage. This is also true of the tunnel linings. Numerous indeed are the chemical compounds, patented and otherwise, some of secret and others of known composition, which have been recommended for waterproofing concrete, by incorporation into the mass or by superficial application. Many have been tested. Some have proven harmless, a few beneficial—at least for limited use—and many detrimental to the impermeability and other qualities of the concrete.

In view of the low price and excellent quality of modern Portland cement when carefully manufactured, it has been proven by repeated tests that the cheapest, surest and most effective means for rendering concrete impermeable in such structures as make up the Catskill waterworks are the liberal use of cement and the intelligent and faithful mixing and placing of the concrete. Incidentally, the additional cement increases the strength of the concrete and is otherwise beneficial. Coarse and fine aggregates must be intelligently selected, of proper variety of sizes, suitably graded and adapted to the structure in hand. Mixing of the aggregates and cement must be thorough; concrete is commonly insufficiently mixed. Water should be supplied liberally, but the tendency in some quarters

*After completion the masonry is kept moist for about 2 weeks, or until covered with earth. The aqueduct cover embankments are shown in the drawings. Rock is permitted in portions of these embankments, because earth is scarce along some parts of the line. Foundation embankments beneath the aqueducts, wherever used, are constructed with great care, of selected earth free from organic material and stones exceeding 3 inches in diameter. This earth is spread in thin layers, moistened, and very thoroughly compacted, usually by rolling repeatedly with heavy grooved rollers. After the compacting, each layer is about 3 inches thick. Scrupulously constructed, such embankments are free from appreciable settlement. The lower portions of masonry dams are also covered with refills and embankments.

now-a-days to a superfluity of water is almost as objectionable as the opposite fault of some years ago.*

Quality of Water: Filtration and Aeration.

The quality of the Catskill Mountain water is so excellent that filtration is not immediately necessary. Nevertheless, as a provision for such treatment in the future, if found necessary

FIG. 30.—FILTER FOR CAMP AND TUNNEL DRAINAGE, CROTON DIVISION, CATSKILL AQUEDUCT.

on account of large increase of population on the watersheds, or for other reasons, an area suitable for filter construction has been secured at Eastview, about three miles southwest from Kensico dam and close to the aqueduct. This filtration plant,

*Beyond dispute, in the writer's observation, the detail of successful concrete fabrication most commonly disregarded is the necessity for keeping the concrete quite moist, from the time it first hardens or when the forms are removed, for a period of from several days up to 2 weeks, according to weather, season and exposure, or until covered by earth or other permanent protection. When joining new concrete to old, or when applying plaster or a brush coat, the older surface must be scrupulously clean and thoroughly saturated with water. The plaster or brush coat should be kept moist for a few days, and, it should scarce need be said, such work ought not to be exposed to freezing or to a scorching sun. See chapter 29.

if built at once, would be much larger than any now in existence.*

Long storage in the great reservoirs will do the water much benefit by sedimentation, and by the bleaching and oxidizing action of wind and sun. Further means of enhancing the quality at slight cost will also be availed of, namely, aeration. Fountains† for this purpose, large enough to treat the full capacity of Catskill aqueduct, are being built at the headworks, where the water is drawn from Ashokan reservoir, and at the outlet of Kensico reservoir.

Construction Forces and Camps (Sanitation and Welfare).—Laborers to a maximum of 15,000 to 18,000 are required during the busiest years of construction at the reservoirs and along the aqueduct. In rural districts accommodations did not exist for this temporary population. Camps built by the contractors, therefore, became necessary. For many reasons it is of prime importance that these camps should be sanitary and under control. To this end requirements have been more particular in the Catskill contracts than in those for any large previous enterprise which has come to our notice. In general, land for camps has been provided by the city, thus making more thorough control possible. Several camps are unavoidably situated within the Croton and other watersheds of municipal supplies; for these camps drainage systems and purification plants, including incinerators for garbage and excreta, have been provided, and

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*For the protection of the water's quality, all buildings, trees, bushes, and other objectionable organic matter will be removed from the reservoir bottoms and sides. Swamps will be covered with clean earth, or ditched, drained, and the peaty material burned, or, in other cases, the muck will be removed. Exposed clay banks will be protected from erosion, so as to prevent roiling the water. Places of shallow flowage will be partly excavated and partly filled with earth. Local house drainage will, whenever necessary, be diverted or treated. Bodies will be removed from all cemeteries within any reservoir.

†These have taken the form of shallow concrete basins about 460 feet long by 240 feet wide, each to contain 1600 nozzles through which water jets can be forced 20 to 50 feet into the air; these nozzles will be of such form that the water will be divided into very fine spray, thus shaking out undesirable occluded gases—hydrogen sulphide and carbonic acid—and exposing the water very thoroughly to the oxygen of the atmosphere. Pipes beneath the basins, and valves in a nearby gatehouse, are so arranged that the number of jets in action, their hight and the quantity of water can be conveniently controlled. From the basin the water will flow directly into the aqueduct. A few moments' reflection will show that these two aeration plants will far exceed in magnitude the grandest fountains built for display purposes—even the far celebrated fountains of Versailles. Such an opportunity for enjoyable, in connection with utilitarian, effects has not been wholly neglected. By symmetrical grouping of the nozzles, architectural form for the basins and pleasing landscape settings, it is planned to make the aeration fountains attractive.

they have been under especially rigid surveillance by the sanitary expert and his staff. Questionable drainage entering a stream, and, in some instances, the whole flow of the stream, is being treated with chlorinated lime.

FIG. 31.—SANITARY CONDITIONS SHOWN BY A GENERAL VIEW OF CAMP FROM BETWEEN STABLES AND COOK HOUSE AT NORTH END OF CAMP.

FIG. 32.—SANITARY CONDITIONS AS SHOWN BY THE ITALIAN COOK HOUSE AND INCINERATOR, CAMP BLAKESLEE, FROM SOUTH.

In all camps vaccination and other preventive measures are enforced, as well as general cleanliness and sufficient light and

air. A few paragraphs from some of the specifications will indicate the safeguards the city is endeavoring to maintain.*

Photographs reproduced herewith show parts of the Ashokan camp and camps within the Croton watershed. Undeniably they register a long step in advance over the old-fashioned huts and shanties, huddled close together, which made up the labor camps quite universally not many years ago, and which are still not unknown in communities claiming to be highly civilized. The success of the city's efforts along the lines of better welfare deserves much credit, and no small meed of praise should be accorded the enlightened contractors who have co-operated so effectively. Strange as it may appear, the greatest hindrances have come from the local small communities for whose benefit, in no small part, these efforts have been put forth by the city. For example, the strenuous endeavor to eliminate saloons and other places of low resort have been countervailed by the licensing of such establishments by the towns and the leasing to their proprietors of private property, often closely adjoining the city's camps, over which, of course, the city's officials have no control.

With the Catskill water works completed, the Croton and Ridgewood systems properly maintained, and, at some convenient future date, the Suffolk county supply added, America's metropolis will have a water supply system which, for completeness, security and permanence, will be matchless.

SPECIFICATIONS RELATING TO SANITATION, SAFETY AND WELFARE.†

Quotations from contract for main dams of Ashokan reservoir.

(Similar requirements in most construction contracts).

Water Supply.—The Contractor shall provide at convenient points ample supplies of water of proper quality for all the operations required under this contract. A proper piping system shall be installed, maintained and extended from time to time to distribute this water to the various

*For the main dams of Ashokan reservoir the camp is a veritable town and has been styled "Camp City." Built within a few months in the midst of the wild woodland, it has streets, sewers, a sewage disposal plant, water supply system, street lights, telephones, fire apparatus, a large department store, an ice house, a bank, a hospital, day and evening schools, clubs, a band stand and a bakery, besides the contractor's offices, machine shops and power plant; its population mounts as high as 3000. Many comfortable cottages have been erected for families, and the total number of buildings is about 250. In a few years, however, when the work shall have been completed, all this must be obliterated thoroughly, so that "the place thereof shall know it no more."

†These are inserted to assist authorities in other cities.

portions of the work where it is needed. Wherever necessary the water shall be under sufficient pressure to give an effective stream from a nozzle for cleaning ledge rock or masonry on which masonry is to be built, for washing stones to be used in masonry, for sprinkling masonry, for wetting embankments, and for other purposes.

Fire Protection.—Hose connections and hose, water casks, or other sufficient means shall also be provided for fighting fires in the more important temporary structures, and responsible persons shall be instructed as to the operation of such fire apparatus, so as to prevent or minimize loss of time from fire.

Drinking Water.—The water supply furnished by the Contractor shall include a sufficient supply of drinking water of good quality to be furnished to all his employees. He shall furnish sufficient water, and ample bathing and clothes washing facilities for his employees.

Quarters and Stables.—The Contractor shall provide suitable and satisfactory buildings for the housing, feeding and sanitary necessities of the men and suitable stabling for the animals employed upon the work.

Medical and Surgical Attendance.—The Contractor shall retain the services of one or more qualified medical and surgical practitioners, who shall have the care of his employees, shall inspect their dwellings, the stables and the sanitaries at least once a week, or oftener if the health conditions of any portion of the camp shall make more frequent inspection desirable, and shall supply medical attendance and medicines to the employees whenever needed.

Hospitals.—The Contractor shall provide one or more buildings, properly fitted for the purposes of a hospital, with facilities for heating and ventilating in cold weather and for screening and ventilating in warm weather. These hospitals shall have an ample number of beds to properly care for sick or injured employees, and shall be provided with all articles necessary for giving "First Aid to the Injured," as well as with all necessary medicines and medical appliances for the proper care of the sick and injured. Another suitable building shall be provided and equipped as a contagious hospital, and any employee, who shall be found to have a contagious or infectious disease, shall be at once removed from the camp to this hospital, and there properly isolated and treated. The Contractor shall give the Engineer satisfactory assurance that the above medical and hospital arrangements have been made.

Sanitary Conveniences and Sewage Disposal.—Sanitary conveniences for the use of all persons employed on the work shall be constructed and maintained by the Contractor in sufficient number, in such manner and at such places as shall be approved. All persons connected with the works shall be obliged to use these conveniences. The sanitaries shall be connected with one or more disposal plants, where all sewage shall be treated, so as to yield a reasonably clear and colorless effluent, free from disagreeable odor. Samples of the effluent shall show no increase in the oxygen consumed after being kept three days at a temperature of 80° Fahr. In addition to the above, pan-closets shall be provided and properly cared for at convenient points on the parts of the work remote from the disposal plants, whenever necessary for the prevention of nuisances. The Contractor shall rigorously prohibit the committing of nuisances within the limits of the work.

Garbage Disposal.—Garbage, both liquid and solid, shall be promptly removed from the buildings and immediately placed in approved tight receptacles of sufficient capacity for about one day's ordinary production. At least once in twenty-four hours all such garbage shall be incinerated or otherwise thoroughly and satisfactorily disposed of so as not to create a nuisance.

Sanitary Precautions to Be Satisfactory.—The sanitary precautions, including those to prevent contamination of the waters of the Esopus creek, and the care of the employees shall at all times be satisfactory to the Engineer, to the Department of Health of the City of New York, and to the State Board of Health. The Contractor shall promptly and fully comply with all orders and regulations in regard to these matters.

Quotations from a contract for work on Croton Watershed.

Intoxicating Liquors.—The Contractor shall not sell on or about the works and shall neither permit nor suffer the introduction or use of intoxicating liquors upon the works embraced in this contract nor upon any of the grounds occupied or controlled by him. (This is in all contracts.)

Ventilation.—A supply of fresh air sufficient for the safety and efficiency of workmen and engineers shall be provided at all times throughout the length of any tunnel or shaft, especially at the headings, and provisions shall be made for the quick removal of gases generated by blasting or by dust-producing machinery if installed in the tunnel. No men, other than members of firing gangs, shall be required to work in air in which carbonic acid gas is in excess of 15 parts in 10,000. Ventilating plants shall be so arranged that either the plenum or the exhaust method can be used and changes from one system to the other made at will. (In all tunnel contracts. Experience has indicated that a somewhat higher proportion of carbonic acid gas may be allowed.)

Safety Devices for Shafts.—Buckets used for hoisting materials during the sinking of shafts shall be equipped with cross-heads which run on guides. Cages shall be used for hoisting men and materials during the construction of the tunnel, and full precautions shall be taken to insure perfect safety. These precautions shall include safety-catches of best design, with bronze or bronze-bushed bearings, landing dogs at all landings, and effective devices for the prevention of over-winding. The efficiency of all safety devices shall be established by satisfactory tests before the cages are put into service, and at least once in three months thereafter. Cages shall be provided with strong protective roofs. The shafts at their tops shall be closed with tight hatchway doors. All doors and hatches shall close automatically. Effective and reliable means shall be provided for indicating at all times to the hoisting engineman, the position of buckets or cages. In addition to the telephone system, effective and reliable signaling devices shall be maintained at all times to give instant communication from the foot of the shaft and each intermediate station to the engine room. (In all contracts involving shafts.)

Sanitary Precautions.

Sanitary Precautions.—The Contractor and his employees shall prevent nuisances in and about all camps and works; shall protect watercourses, reservoirs, wells and other sources of water-supply, public or private, from pollution, contamination or interference; and safeguard the public health, as may be directed from time to time by the constituted authorities of the State and City. The Contractor shall summarily dismiss and shall not again engage, except with the written consent of the Engineer, any employee who violates this section.

Inspection by Engineer.—The Engineer shall have the right, in order to determine whether the requirements of this contract as to sanitary matters are being complied with, to enter and inspect any camp or building or any part of the works, and to cause any employee to be examined physically or medically or to be vaccinated or otherwise treated; also to inspect the drinking water and food supplied to the employees. The sanitary precautions, the care of the employees, the camps and all terri-

tory occupied by the Contractor, shall at all times be satisfactory to the Engineer.

Compliance with Sanitary Regulations.—The Contractor shall promptly and fully, and in every particular, comply with all orders and regulations in regard to these matters, including all sanitary and medical rules and regulations which may have been or may be promulgated from time to time. And to this end and to properly preserve the peace, the Board of Water Supply Police shall have the right of access to the Contractor's camps and quarters.

Quarters and Stables.—The Contractor shall provide suitable and satisfactory buildings for the housing, feeding and sanitary necessities of the men and suitable stabling for the animals employed upon the work. All buildings for these or kindred purposes shall be built only in accordance with approved drawings and specifications at designated places. All houses occupied by employees shall be thoroughly screened to exclude mosquitoes and flies. The quarters for the men shall be grouped in properly arranged camps. Camps shall, if ordered, be enclosed by satisfactory man-proof fences with not more than two entrances. Each camp and the grounds surrounding it in all directions shall be thoroughly illuminated by electric arc lamps or other acceptable lights. This illumination shall be maintained from sundown to sunrise every night during the occupation of the camp, unless otherwise ordered. Employees may, so far as practicable, be required to remain within camp when not at work.

Sanitary Conveniences and Disposal of Excreta.—Buildings for the sanitary necessities of all persons employed on the work, beginning with the first men employed to build camps or for other preliminary operations, shall be constructed and maintained by the Contractor in the number, manner and places ordered. All persons connected with the works shall be obliged to use these conveniences under penalty of discharge. Unless otherwise directed, the sanitaries shall be provided with water-tight removable receptacles of suitable capacity. These receptacles, if used, shall not be allowed to overflow, but shall be removed, without spilling, at required intervals, their contents at once treated as directed, and then promptly taken to a designated place ouside the watershed. and there disposed of as ordered. If incinerators be used, they shall be efficiently operated. (Incinerators have been generally adopted; usually of the McCall type.)

Attendants.—The Contractor shall provide a sufficient number of acceptable attendants to keep all sanitaries in satisfactory condition and compel employees to use them.

Preventing Nuisances.—The Contractor shall rigorously prohibit the committing of nuisances, within the tunnels, the aqueduct, or other completed or partially completed structure, or upon the lands of the City, about the works or upon adjacent private property.

Medical and Surgical Attendance.—The Contractor shall retain the services of acceptable qualified medical and surgical practitioners, to the number ordered, who shall have the care of his employees, shall inspect their dwellings, the stables and the sanitaries as often as required, and shall supply medical attendance and medicine to the employees whenever needed.

Hospitals.—The Contractor shall provide, from approved plans, one or more buildings, properly fitted for the purposes of a hospital, with facilities for heating and ventilating in cold weather, and for screening and ventilating in warm weather. These hospitals shall have an ample number of beds to properly care for sick or injured employees, and shall be provided with all articles necessary for giving "First Aid to the Injured," as well as with all necessary medicines and medical appliances

for the proper care of the sick and injured. Another building of approved design shall be provided and equipped as an isolation hospital, and any employee who shall be found to have a communicable disease, shall be at once removed from the camp to this hospital, and there isolated and treated as directed. Whenever practicable, an employee having a communicable disease shall be removed when and as directed to a hospital outside the watershed.

Medical Supervision of Employees.—The medical supervision of the Contractor over his employees shall extend to the physical and medical examination of all applicants for employment, in order to prevent persons having communicable diseases from becoming connected with the work, and the Contractor shall employ only persons shown by such examination to be free from communicable diseases. Whenever, in the opinion of the Engineer, it is necessary for the protection of the public health or the health of the employees, the Contractor shall remove any employee from the work either to a hospital at or near the works or to a more remote hospital, or shall remove permanently from the work or any camp any employee whose presence is believed to endanger the health of other persons.

Health Reports.—Once each week, or more frequently if required, the Contractor shall give the Engineer, in such detail as may be prescribed from time to time, a written report, signed by a physician in regular attendance, setting forth clearly the health conditions of the camp or camps and of the employees. If any case of communicable disease be discovered or any case of doubtful diagnosis, it shall be reported at once to the Engineer, by telephone or messenger, and confirmed in writing.

Domestic Water-Supply.—The water furnished by the Contractor shall include a sufficient supply of drinking water of acceptable quality for all his employees, to be obtained from approved sources.

Bath and Laundry Facilities.—He shall provide ample bathing and clothes-washing facilities for his employees and sufficient water of acceptable quality therefor. If any water-supply for domestic uses should become contaminated, the Contractor shall promptly provide a new supply from an approved source and abandon the contaminated supply, or shall provide works for purifying the contaminated water, when and as ordered.

Disposal of Wash Water and Stable Drainage.—All wash water from kitchens, laundries, and other places, and all drainage from stables, shall be conveyed by satisfactory means to places directed, where such drainage shall be treated by the means ordered so as to yield an acceptably innocuous effluent.

Drainage from Camps and Tunnels to Be Filtered.—Drainage from camps and tunnels and from other places yielding water unfit for direct discharge into a reservoir or tributary thereof shall be conducted in tight drains or other approved conveyors to filters, septic tanks or other disposal plants of approved construction, at places designated, and treated as directed to produce an acceptable effluent. Such effluent shall be discharged only in the manner and at the place or places directed.

Garbage Disposal.—Garbage, both liquid and solid, shall be promptly and satisfactorily removed from the buildings and immediately placed in approved tight receptacles of sufficient capacity for about one day's ordinary production. At least once in every twenty-four hours all such garbage shall be incinerated or otherwise thoroughly and satisfactorily disposed of in an approved manner.

CHAPTER IV

Purification of Water.

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We use water over and over again. The same drop that now falls as rain has so fallen before; perhaps not here nor yesterday, but somewhere at some time. Having fallen it receives its modicum of dissolved or suspended impurities and hurries to the ocean only to be again raised by solar heat, leaving its load behind to be taken care of by the sea. This cycle of changes goes on throughout the ages, with the result that the ocean depths grow more shallow and the mountains become washed down to the level of the plains. It is because of the operation of this cycle that the sea is salt.

A part of this load carried by the rain, the run-off, the rivulets, streams and rivers, consists of sewage material, of which we are afraid. All the pollution gets to the ocean eventually, but before reaching there much of it undergoes great changes which render it harmless to health, or else it is temporarily separated from the water which carries it and during such period of separation the water may be drunk by man.

These changes and separations are brought about by what we term "processes of purification," some of which are carried on by nature, while others are the result of human endeavor. Let us observe some of Nature's methods.

Sedimentation.—The mere word is full of meaning, the veriest tyro being able to comprehend what is meant; and as a mode of purification sedimentation must take rank as of the very first importance. We have already noted that extraneous matters carried by water may be either dissolved or suspended, but it is of the latter form of material that we entertain the greater fear. It is true that notable quantities of sundry inorganic salts in solution will give water medicinal or even poisonous qualities, but the true pathogenic items are the disease germs held in

suspension and these, having weight, are capable of sedimentation and consequent removal from the water supply. A very good illustration of what sedimentation can do in the way of purifying a river water is to be found in the case of the Illinois river. During periods of high water the river overflows its banks and becomes greatly widened, the river flood-plain permitting of shallow flowage over a decidedly large area of land. Under such circumstances particles of suspended material have but a short distance to fall before reaching the bottom of the flooded district, and the beneficial results are to be noted in the improved character of the water flowing from such area. This principle of improving a water by permitting suspended material to fall but short distances was brought out in a patent some years ago, whereby water of a turbid nature was greatly improved by passing it in a zig-zag course through a tall vessel filled with horizontal shelves placed near together. The distance was so short through which the falling particle had to pass, that it reached a shelf during the available time interval and remained there. So it is in the case of the overflowed river flood-plain.

It may be worth while to call attention to the assistance given by silt in removing bacteria during sedimentation. This point was pretty thoroughly investigated years ago and there will be found upon record the great difference in total count of bacteria in the upper levels of deep water when the germs were permitted to sink in clear and in turbid water. Of course, one will not argue from this, as some have done, that turbidity, *per se,* is serviceable even when sedimentation is omitted, because it must be apparent that swallowing turbidity, germs and all, cannot be of advantage.

Time.—Time is the other great factor to be counted upon in natural purification of a surface water. In fact, it is scarcely too much to say that beyond "sedimentation and time" there is little more that is worthy of consideration. The two run side by side, of course, for sedimentation demands time in order to be efficient, while time is usually, but not always, accompanied by sedimentation. It is apparent that during long but rapid stream flow the item of sedimentation might be practically absent. The value, then, of "time," with or without sedimentation, is

that it allows adverse conditions to act fatally upon the germs of disease, so that they are rendered harmless in the event of their actually arriving at the point of intake. Even though they should arrive while yet living, it is very possible that they still might be harmless, for the reason that, because of their lack of vigor, their power of producing disease might be readily neutralized by the natural resistance of the human organism.

It may be asked what is the required time for safety, and the answer to the question is difficult to give, as there are so many conflicting data. Jordan's experiments upon the typhoid germs immersed in the water of the Chicago drainage canal are classic and go toward showing that those organisms cannot survive more than a few days under such adverse circumstances. At any rate the very great majority of them cannot so survive, which conclusion appears supported by investigations touching upon bacterial life in the Illinois river.

If it be impossible to say how much longer certain especially vigorous individuals of the typhoid family might live beyond the time allotted their more numerous but weaker relatives, we think, however, that they would not live for long. One thing is both certain and fortunate, and that is that through the agency of those two great factors of safety, "time and sedimentation," so great a decrease occurs in the number of germs of water-borne disease that humanity is protected from epidemics that would otherwise all but depopulate the earth.

It would be well to here point out the wise observation made by Jordan that the purification of a stream judged from the chemical standpoint may not take place with the same degree of rapidity that it would if considered from the bacterial point of view, for the reason that bacteria may die during a shorter interval of time than would suffice for the oxidation of organic matter not bacterial.

Aeration.—Aeration is, according to the popular view, the best form of water purification, unless we possibly except the action of direct sunlight. As a matter of fact, it is nearly valueless as a disease preventer, and is efficient only as a destroyer of taste and smell, or as a means for iron removal. Take, for example, the water supply of the city of Niagara Falls, drawn, as it is, from the Niagara river, just above the cataract. No

better natural aeration could be secured than is manifested in that instance, and if the sewage of a city like Buffalo could be disposed of by the aeration of water, then the supply of Niagara Falls should be rated as safe. The typhoid death rate of the city, however, is the highest in the State of New York, and one of the highest to be found anywhere, and why? Because the sewage of Buffalo is yet in the water and aeration as furnished by the Niagara rapids has failed to purify.

Aeration has its uses, however. A Western city which I have in mind is supplied with water from a deep source and the water smells so strongly of sulphureted hydrogen as to be objected to by the people. Simply tossing that water into the air shakes out the dissolved gas and removes all occasion for objection. A similar condition of affairs obtains at Jacksonville and St. Augustine, Fla., where the deep artesian waters are delivered some 15 feet above the surface of the ground. By simply falling from that altitude the contained sulphureted hydrogen is removed and smell eliminated. Again, take the case of Rochester, N. Y. Aeration is resorted to there; not because it is really needed, but for the reason that the great head under which the water reaches the city may be reduced by a reservoir fountain, with the result that a safe pressure is thrown upon the local mains and a desirable attraction is added to the city parks.

As I have already said, the public sets great store by aeration, its operation is always attractive and it often does much good. Moreover, the public pays the bills. Therefore, although such a process will not protect against water-borne disease, nevertheless, because of its attractiveness and because of the value set upon it by the people at large, it is wise to institute reservoir fountains and such like devices, provided they can be established without undue expense.

One additional word may be said here as kindred to this topic. If a stream should be called upon to carry so great a load of sewage inflow that the dissolved oxygen became exhausted, then nitrification would cease and a nuisance would surely result. See to it, therefore, that the natural aeration of the water be not so lowered as to prevent the stream "taking care of itself."

Light.—Light, especially direct sunlight, as was said a few lines back, is most favorably considered by the public when water purification is up for discussion. There is no question of the germicidal action of the direct solar rays, but the trouble lies in the fact that there is no great power of penetration to this form of water improvement. Sterilization will take place, but it will not be carried to practical depths. In other words, only superficial layers of the water body will be affected beneficially. Of course, we are already familiar with the bacteriographs common to the laboratories of instruction, whereby designs recorded in bacterial growth are made to appear in innoculated jelly after the same has been exposed to direct sunlight; and it has also recently been reported by Weinzirl* that "the results by direct exposure of the bacteria indicate that sunlight is a much more powerful germicidal agent and consequently a more important hygienic factor than it has heretofore been considered; that the bacteria when freely exposed are killed in one-fifth to one-twentieth of the time formerly considered necessary."

All of this being acknowledged, the fact remains that light is a most uncertain agent of safety upon which to depend. One thing it does do, however; it tends to improve the appearance of a colored water if the time of exposure be prolonged. We notice this bleaching effect as the result of months of storage in an open reservoir. It may be said here broadly that light does no practical good at any time and it may do material harm, because if a water become seeded with taste-producing algæ, sunlight will favor their growth, whereas that same water stored in the dark will remain permanently in good condition. No one could find a better illustration of this adverse action of light than the instance of the "asterionella plague" of Brooklyn. It may be recalled that the seeded ground water developed immense numbers of the objectionable growth as soon as it was exposed to light in the Ridgewood reservoir.

To touch upon another local instance, I well remember that it was once proposed to cover the old 42d street reservoir and utilize the covering roof for some sort of public enterprise. It was objected that cutting off the sunlight would damage the water. Water is never damaged by being stored in the dark,

*Science, XXVI., 598.

and certain waters must be always so stored. There is an easy rule to follow: "Filtered waters and waters which come from the dark, such as ground and deep seated waters, must be stored in the dark. Surface waters may be stored in the dark or light, whichever is more convenient."

A much more efficient means of natural purification and one of which the public knows but little is that of "nitrification and intermittent soil filtration." Suppose that a deposit of nitrogenous organic material is made in the upper soil. Swarms of bacteria attack it, the complex nitrogen-bearing molecules are broken up, processes which we classify as putrefactive are instituted, more simple molecular structures result, and finally the nitrogen finds itself as a constituent of some "nitrate" and as such is available for plant food. This, in the rough, may be termed the cycle of organic nitrogen. Taken up by the plant, the nitrogen becomes a portion of its body, as such is devoured by an animal and is returned to the soil as animal waste material, to again run its course through the cycle as before.

At one portion of this endless circle of changes we humans find the nitrogen atom objectionable because of its associates, while at another point upon the periphery it helps to sustain our life; and so the change goes on to the end of time.

Intermittent Filtration.—You will observe that in speaking of soil filtration above I interjected the word "intermittent." It is most important. If the dose of waste material, which above we supposed added to the soil, be too great, or if it be too frequently applied, then purification ceases, because the nitrifying organism which works these changes will quit its efforts if too much be given it to do. Atmospheric oxygen must follow a dose of sewage in order that nitrification may proceed with certainty. A continuous stream of polluting material will pass through the soil practically unchanged. Now, what do we gain from this? First, we learn that the beneficial action of soil filtration is immensely strong. Second, that strong though it be, we should not overtask it. Sooner or later everyone will encounter instances where an astounding amount of pollution will be taken care of by a remarkably small quantity of soil lying between the point of pollution and the water supply, and wonder will be aroused at the amount of protective power manifested by the intervening

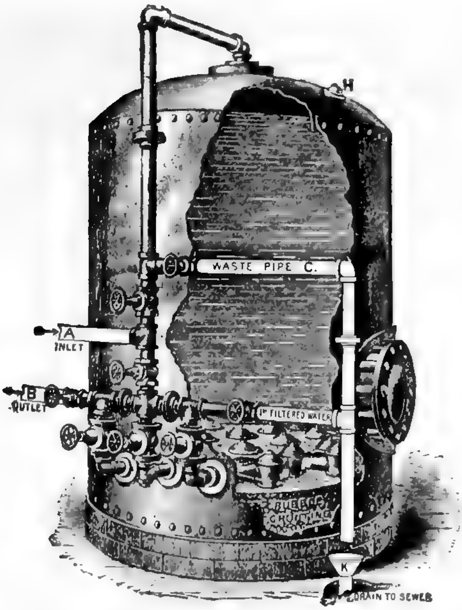

FIG. 33.—AUTOMATIC PRESSURE FILTER.
(From Mason's *Water Supply.*)

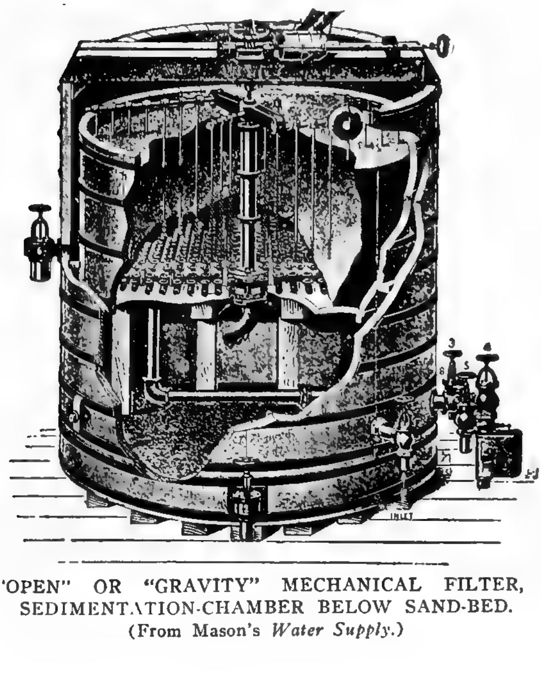

FIG. 34.—"OPEN" OR "GRAVITY" MECHANICAL FILTER, SHOWING SEDIMENTATION-CHAMBER BELOW SAND-BED.
(From Mason's *Water Supply.*)

layer; but beware of all such instances, for it cannot be predicted when the nitrifying process will quit work and allow an unchanged sewage to pass the barriers. If I were not afraid of quoting an old story, I could tell of a celebrated case where a cesspool delivered a raw sewage to a well during periods of stormy weather, when the filtering power of the soil was overtaxed, although at other times purification was complete. It is worth noting that when the cesspool was closed, the well, which never failed before, ran dry.

Cold, the effect of freezing, has been relied upon for its germicidal power for many a year, and it is interesting to note the fluctuations of opinion as to its enfficiency. We first believed it to be reliable and we considered ice as pure, paying little regard to the source whence it had been collected. With the advent of bacteriology we changed our views as to this, because we found that bacterial cultures, which had been exposed to such low temperatures as that of solid carbon dioxide or even that of liquid air, continued to grow as soon as ordinary temperature was resumed. Our error lay in basing our conclusions touching the non-germicidal power of cold upon qualitative rather than quantitative determinations. By more recent and more careful investigation we now know that a very high degree of mortality results among bacteria which are exposed to cold, nor need it be a very great cold. Smith and Swingle* have shown that the critical point appears to be somewhere around 0 deg. C. and that an organism which can pass this point in safety will probably not be harmed by a much lower temperature. They conclude that different bacteria are injured by freezing to very different degrees, behaving in this respect like the higher plants and animals; fortunately, the *bacillus typhosis* is destroyed in great numbers by even short freezings.

From the practical standpoint we now know that ice is much purer than the water from which it is frozen, this being true partly because of the mechanical exclusion of floating material during the process of freezing, and partly because of the gradual death of bacterial organisms during the months of storage to which ice is commonly subjected. There is no question but that ice frozen upon deep water may be counted upon as possessing

**Science,* XXI., 481.

A purification of at least 95 per cent. and usually decidedly more than that, and, as has been already stated, old ice, such as that delivered in summer, has a still greater factor of safety.

It would go almost too far to enter upon the question of the destruction of disease producing organisms by the adverse action of life native to and commonly found in water, but such action does take place and is to our advantage, difficult as it may be to set a value upon its exact amount.

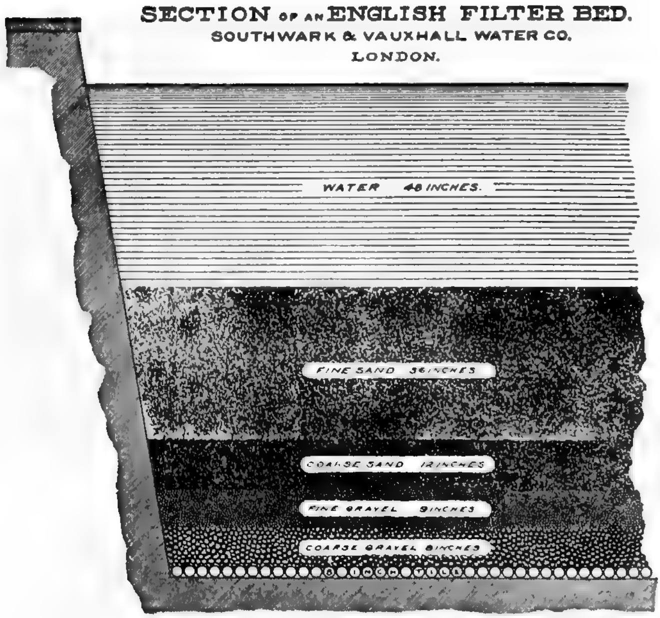

FIG. 35.—(From Mason's *Water-Supply.*)

When we come to the consideration of the artificial purification of water we open up a large subject, indeed; one vastly too great to be disposed of in the space here available. Glancing then hurriedly over the field let us first touch upon the question of—

Slow Sand Filtration.

This is sometimes known as the English filter bed system and consists of a suitable reservoir, holding a bed of sand

about four feet thick and efficiently underdrained. Upon this bed water is admitted to the depth of several feet and filtration is accomplished at the rate of about three million gallons per acre per day. The system is an old one and it is inter-

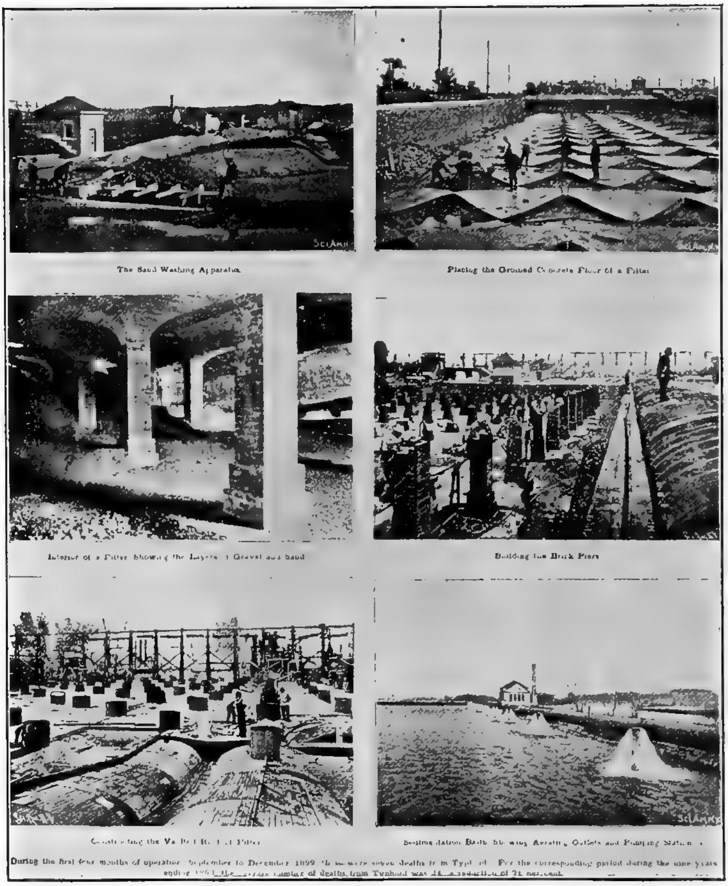

FIG. 36.—FILTRATION PLANT FOR THE CITY OF ALBANY. DESIGNED AND ERECTED FOR THE REMOVAL OF TYPHOID BACTERIA FROM THE WATER SUPPLY.
(Courtesy of *Scientific American*.)

esting to observe how confidence in its efficiency has fluctuated. At the outset, practical results were so apparent that the sand bed was accorded the greatest confidence. Later, when bacteriology was born, it was declared that the objectionable germs

which we sought to remove were so small as to be able to pass many abreast through the spaces between the sand grains. Thereupon came serious doubt as to the value of sand filtration. As further study of the process was pursued, the true action of the filter became apparent, and we then saw that we were not dealing with a simple strainer, but that each of the sand grains constituting the bed became coated through bacterial action, with a sticky, jelly-like substance termed "zooglea" jelly, which seized and retained such material as collided with it, and that throughout the bed conditions were established unfavorable to the continued life of pathogenic organisms. The slow sand filter as a device is, of course, not perfect—few products of human invention are—but its efficiency is very high and its practical value as a safeguard against disease is unquestioned. The reduction in the number of bacteria present in the raw water amounts to something like 99 per cent. in a well designed and well constructed plant, and in view of the fact that harmless organisms greatly outnumber those of objectionable character, it is simple arithmetic to show that the element of safety is marked when ninety-nine out of every hundred organisms of all kinds are removed.

Of late a number of plants have been constructed possessing "pre-filters" or "scrubbers," as they used to be called, and this with a view of lightening the load thrown upon the filters proper and increasing the time between cleanings by supplying to them a water of improved quality. Such a modified plant may be seen at the Torresdale Station of the Philadelphia works and an idea of what the "pre-filters" will do may be had from the recent report, viz.:

Bacteria per cc. in raw water...........	8700.
Bacteria per cc. after passing pre-filters..	3684.
Bacteria per cc. after passing final filters..	81.

The length of time that a filter will run without cleaning will, of course, vary with the filter and with the character of the water it is called upon to purify. Perhaps in the rough it might be said that during the summer time cleaning will be required every three weeks or thereabouts, while in winter the life would be perhaps three times as long. In the form in which the Albany

filters were first constructed, before the scrubbers were added, 26 days was the average time between cleanings.

So far as the method of cleaning is concerned, it is probably already generally known that about half an inch of the upper sand, containing what is technically termed the "schmutzdecke," is removed, washed and returned. The old form of accomplishing this by removing the dirty sand with shovels, wheeling it out, washing it by hand and wheeling it back, has been greatly modified, and labor-saving devices have been instituted which greatly cheapen the process. To enter into a consideration, however, of these changes would carry us much beyond our

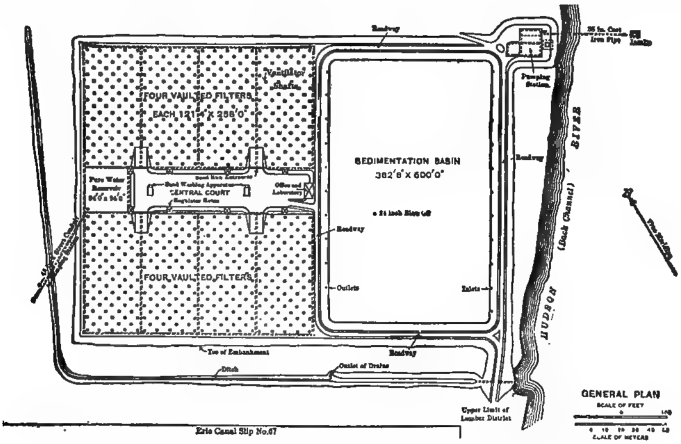

FIG. 37.—FILTERS AT ALBANY, N. Y. (HAZEN.)
(From Mason's *Water Supply.*)

limited space. So far as the expense of cleaning is concerned, per million gallons of water filtered, let it be said that in the Torresdale plant it amounts to 35 cents for the "labor of scraping and washing sand." It should be said that the "pre-filters" of the Torresdale station so improve the raw water as to permit the final filters to be run at a rate of six million gallons per acre per day.

It goes without saying that the cost of cleaning will greatly vary with the character of the material to be removed from the sand, with the cost of labor, and with sundry other variable conditions. I remember to have seen one bed in England which contained material so compacted upon the sand surface that there was no option but to remove it by hand in the old-fashioned

way, and as the barrow loads left the bed they greatly resembled piles of old linen cloth.

Rapid Filtration.—I could, of course, take up much time by detailed description of that rival of slow sand filtration, known as the American or Mechanical system. Let it suffice, however, to say that it differs from the older method chiefly in two points: first, its much greater rate of filtration; and second, the addition of a chemical. The gain in rate is very great, being about 125,000,000 gallons per acre per day, in place of the 3,000,000 of the older system. It is the use of alum, however, in connection with this filter that marks its most prominent peculiarity. The use of this "coagulant," as it is termed, is a point of objection with not a few people, they being inclined to oppose the admission of such material to their food. The readiest illustration that I can think of, and one which I have often used, is to compare the action of alum in mechanical filtration to the action of an egg in clearing coffee. The coagulated albumen of the egg, holding as it does the entangled coffee grounds, very aptly represents the aluminum hydrate resulting from the decomposition of the alum, which in its turn holds entangled in its sticky mass the suspended matters of all kinds present in the water. The aluminum hydrate, with its load of separated material, no more gets into the drinking glass than does the egg albumen, with its entangled coffee grounds, reach the cup. In each instance such material goes to the sewer.

So far as efficiency is concerned, there will not be found any material difference between these rival systems of filtration. Well constructed plants of either type will give equally excellent results if properly managed; but there is a choice to be exercised between them in most instances, and it will be necessary for the person in charge of the case, being governed by the local conditions, to make proper selection. Should the water be a heavily stained one, its color will be more readily removed by a mechanical plant. Should the city be a large one, and the price of ground be not too high, there are many advantages in a slow sand bed. The latter form of filter has no alum bill for which to provide, but again, its interest charge is likely to be higher. A combination of the two systems is not unknown, and plants will be found of the slow filtration type fitted with devices

for the use of alum, or other coagulant, followed by sedimentation for the partial removal of the coagulated material formed.

Use of Ozone.—During the last few years sundry processes have been patented and exploited for the purification of water by the use of ozone. In brief, such a process consists of the preparation of ozonized air by permitting a current of air to pass through a containing vessel in which an electric discharge is continually taking place. The ozonized air is then forced through the water to be purified, the latter commonly entering at the top of a tall cylinder and out at its bottom, while the ozonized air bubbles through it in the opposite direction. Unless the water be clear in character, a filter plant must, of necessity, be an attachment to the ozone process, because the ozone does not remove turbidity. One is sometimes surprised, however, at the improvement which the process will make in the physical appearance of a water, even when the filter is omitted. So far as bacterial efficiency is concerned, complete sterility can be secured if sufficient ozone be employed, but even with moderate doses of ozone a favorable comparison can be made with the best filter plants that have been constructed. The weak points connected with the use of ozone are, first, its cost, and, second, the liability of the apparatus to get out of order. These objections will doubtless be overcome in time, and they are reported by those interested as being already overcome. What we need is a municipality willing to take the risk of erecting a large plant operated upon this system. We should all be delighted to study the results obtained, and we should be glad to congratulate such a city in the event of success following its venture; we should also be glad to use the information accumulated, but I question if we would be entirely disposed to share the expense in the event of failure. The ozone process has not gone very far beyond the experimental stage as yet, whatever may be said by those financially interested, and what we lack is a collection of data upon a large scale.*

One ozone proposition with which I was recently connected aimed at passing a turbid river water through a sand bed at a rate of some 200,000,000 gallons per acre per day before ozonization, and when I proved to them that such a rate would not

*Since the above was written, Paris has concluded large scale experiments and has contracted for an ozone plant capable of furnishing 100,000 cubic meters per day.

remove the turbidity, the company replied, "We can do it by the use of a little alum." That answer would scarcely serve, because the establishment of such an addition would result in the erection of a mechanical filter plant supplemented by the ozone process. Of course, that would mean much additional money, and the mechanical plant, properly managed, would give satisfactory results by itself.

On the whole, then, while we admit the efficiency of ozone, and while we look hopefully towards its practical success in the future, we cannot but feel that at the present moment its desirability for introduction as a purifier of a municipal supply is very questionable.

The Peuch System.—It would have been better perhaps to have considered the "Peuch" system of filtration a little further back, as it is a sort of modified sand bed, but just a word about it here. It consists of a system of gravel and sand beds, through which the water passes in succession, entering the coarsest first, containing small stones the size of walnuts, and ultimately leaving the finishing bed of fine sand. It is, in short, an extended system of "scrubbers," but there is no question about the excellence of the result secured. One writer has compared its action to the washing of a glass vessel by using successive volumes of water rather than one washing by the same quantity of water in one volume. The system is being inaugurated near Antwerp for the purification of the supply of that city, and it is already in operation at Magdeburg and sundry other places in Europe. As yet it has not found its way into this country.

Use of Chloride of Lime.—Perhaps the newest method for water purification which we have before us today is the adaptation of something that is decidedly old, viz., the making use of the well-known germicidal powers of "chloride of lime," or "bleaching powder." It, or a corresponding sodium salt, has been suggested before, but has always been opposed on the ground that it was not advisable to "disinfect" a water supply. No one took that ground more strongly than I did myself, but we were all entirely unprepared for the discovery that the amount of the chemical required to do excellent work was in reality well-nigh infinitesimal. In short, doses so small as .03 of a grain per gallon, measured as available chlorine, were found to greatly

reduce the total count of bacteria and to positively kill all those of objectionable character. In experiments which I conducted myself I found that in waters seeded with pure culture of *bacillus coli* and also waters to which had been added pollution in the form of human dejecta, there were left no gas forming bacteria of any kind after a short exposure to the small dose of "bleaching powder" mentioned above. The chemical seems to have a selective action upon intestinal organisms. We are possessed of data dealing with the use of this process upon a large scale, so considerable a city as Jersey City being supplied with water treated by the "bleaching powder" method. So impressed am I with the excellent results secured by the use of "chloride of lime" that I think it no rash prophecy to say that a "bleaching powder" addition will be made to a large percentage of new filter plants, so that during periods of threatening danger, if not during the usual running of the plant, additional safety may be guaranteed. As a notable instance of what this process will do when employed upon a grossly polluted water, let me say that in Chicago I saw the filthy water of "Bubbly Creek," containing an average of 700,000 bacteria per cc., so improved by the "bleaching powder" method that the count per cc. fell to 10. Of course, part of this excellent result was due to the sand filter and the dose of alum employed. The bleach is added after the alum and before filtration.

Unusual Methods.—To deal here with the unusual methods of purifying city water is manifestly impossible, but it is interesting to observe that it was actually proposed upon one occasion, by a would-be purifier, to boil every drop of water distributed to over a million people. The proposition seems odd enough upon its face, but I think the oddest part of it was the apparent fact that it could be done for an amount of money somewhere within fairly reasonable limits. The scheme was, as one would suspect, to apply the heat at a very localized portion of the flowing stream of water and to cool the heated stream by allowing it to warm up the oncoming water. Of course, the plan was discarded, but I am told by the engineer before whom it came for consideration, that the water left the apparatus only about 4 degrees F. above that at which it entered and "the expense, strange to say, was not prohibitive."

Softening Water.—Water purveyors will be at times called upon to erect somewhat costly works for the softening of city water, irrespective of whether it be or be not potable, for a city water has to serve for other purposes than merely domestic use. Boilers have to be run. Dye works and bleacheries have to be provided for, and last, but by no means least, laundry interests must be protected. It is surprising how quickly the varying hardness of a water will find expression in the yearly soap bill. I say varying, because waters, especially stream waters, will differ much at different times of the year. When the rivers are low and much of the water that they contain comes from percolation sources, then hardness increases, while at those periods of the year when storm waters quickly find their way to the drainage channels, volume of flow increases and hardness diminishes. Cases could be quoted where the owners of deep wells, after spending much money for their construction, found it cheaper to abandon the water which they furnished, although they could get it for nothing, and buy city water at fairly high prices.

One may, therefore, be called upon to erect softening works, and in such event he will likely make use of the old patented process known as Clark's, whereby lime water is admitted to the supply with the result that the carbonate of lime originally present, and that which is formed by the process, will together fall as a white powder which may be removed by sedimentation or a filter press.

Not many instances of softening plants on the large scale will be found in this country, although they are common enough in England. Our waters here do not as a general thing require softening, or, to put it differently, it is commonly cheaper to go elsewhere for a softer supply. Should it be asked what amount of hardness would be tolerated, I should be forced to give a somewhat unsatisfactory answer, as so much depends upon the people who are going to use the water. Take, for instance, sundry city supplies of Massachusetts, whose users reported their opinions of the waters in definite terms. I found that complaint was registered in cities with so low a hardness as 31 parts per million, while other towns pronounced their water perfectly satisfactory, although the hardness ran up to 70 parts per million. I fancy that the better way to rate hardness would be to

call everything below 50 parts per million "soft," everything above 100 hard, and to leave the space between 50 and 100 open to discussion and dependent upon local preferences.

As to the wholesomeness or otherwise of a "hard" water, we are plunged in a great deal of conflicting testimony, but I am inclined to adopt the view of English authorities upon this point, and they do not pronounce against a "hard" water unless the amount of contained mineral be very excessive.

"Residual Typhoid."—Manage things how we may, there seems to be a point beyond which we cannot go in lowering the death rate from typhoid fever by improving the water supply. Even should we be able to supply our people with distilled water for domestic use, there would be yet with us what is termed "residual typhoid," which, stated in figures, means 15 to 20 deaths per year per 100,000 inhabitants. Europe is far in advance of us in this matter, and for what reason I must confess is a mystery to me. "Residual typhoid" is the amount of the disease yet with us after the water supply has been accounted for. It is "non-water-borne typhoid." Under it must be listed those cases which come from milk, those which come from filthy habits, resulting in the direct inoculation of food, and those which are to be credited to flies or to sources unknown. Why should we Americans have so high a "residual" rate? As I said before, I do not know. It is not to our credit that it exists and it behooves us to set about lowering it.

Advantages of Modern Improvements.—Finally, let us consider the question that is often to the fore. Are we from a sanitary standpoint better off by these so-called modern improvements? Our fathers did without them; why shouldn't we? In order to approach a question of that kind we must always seek for data from large numbers of people. Figures to be good for anything cannot come from a few scattered instances here and there, covering but few individuals. No better illustration can be given of the advantages of filtration than are published in recent Cherbourg statistics. At the time of the epidemic of 1898 and 1899 the city proper, of a population of 32,000, derived its water supply from the River Divette, with partial purification by an imperfect filter. At the same time the garrison, num-

bering 8,200, was supplied with water from the same source, but without filtration. The typhoid death rates were:

Civil	109 per 100,000
Military	1,893 " "

A second epidemic occurred in 1908 and 1909. At that time the garrison supply was as before, but the city carefully filtered its water by the "Peuch-Chabal" system (the intake being as before). The typhoid death rates were:

Civil	6.5 per 100,000
Military	1,594. " "

There was one barrack within the city and no deaths occurred therein. Again, in 1855, the typhoid death rate for the city of Paris was 284 per 100,000. The most modern one which I have before me is for 1905 and the corresponding value stands 8.8.

Even the total rate for deaths from all causes has markedly improved. Meuriot studied the general mortality in a small provincial city of France, selecting three periods of five years each: 1821 to 1825, 1861 to 1865, and 1901 to 1905, and excluded deaths under 11 years of age. He found the average length of life for the three periods in question to be:

1821-25	54 years, 6 months
1861-65	57 " 2 "
1901-05	60 " 10 "

A net gain of over 6 years.

Any municipal undertaking that will aid in producing results such as those given above must be acknowledged as an improvement which it well pays to make.

CHAPTER V

Milk.

THOMAS DARLINGTON, M.D.,
Formerly President of the Board of Health, New York City.

Of all the foods used for human consumption, milk is the most important. It is the one food for infant life, largely the food of invalids and frequently that of old age.

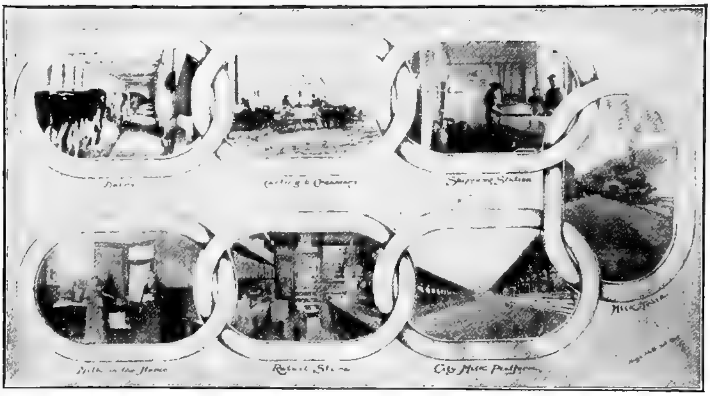

FIG. 38.—THE SEVEN LINKS IN THE HISTORY OF THE CONSUMPTION OF MILK.

Seven Links.—There are seven links in the supply of milk from the time it is produced on the dairy farm to the time it is consumed in the house. The first link is the dairy. The second link is the carting of the milk to the creamery or milk shipping station. The third link is the creamery, where the milk is cooled, bottled and put in shape for shipment. The fourth link is the milk train, upon which the milk is transported to the city. The fifth link is the milk shipping platform, which in cities are large depots where the milk is arranged for distribution. The sixth link is the retail store, where milk, either in cans or bottles, is dispensed to the public. The seventh link is the milk in the

home of the consumer. Over each of these links the Department of Health exercises supervision and control.

If milk could be produced and fed direct from the cow there would be little need of milk inspection and little danger of impure milk, but this happy condition does not exist in large cities. Milk sold in New York is shipped sometimes hundreds of miles and handled several times, hence the situation is far from being a simple one.

The problem of a pure milk supply can be solved when a Department of Health can guarantee that all milk sold within the city limits is drawn from perfectly healthy and normal cows, housed in comfortable and sanitary quarters, milked by a clean and healthy person into a sterile container, quickly cooled, transported and delivered to the consumer in a sealed package. An approximation of such an ideal requires constant efficient inspection.*

The major portion of such a guarantee concerns the health of the cow and the milker, and the sanitary condition of the stable and utensils—that is, the "Dairy Farm"—makes the heaviest demands.

City milk inspection ascertains if the milk contains as much butter-fat and other solids as required by law, while it is the duty of the Dairy Inspector to ascertain the conditions under which the milk is produced.

It is a fraud to adulterate milk by skimming, but this is insignificant, compared to the evil of allowing it to become contaminated by disease-producing bacteria. There is little doubt but that more harm has resulted from the use of milk that has been contaminated through neglect of sanitary precautions than from the use of watered or skimmed milk. Milk is no longer declared pure because it contains the legal quantity of butterfat and total solids; it must now undergo a searching examination for filth and bacteria.

*The Department of Health of the City of New York (the writer refers to this city especially, as he has been closely associated in developing the system which obtains there) has 57 inspectors of Foods assigned to Milk Inspection work. Thirty-three of these Inspectors, with one Inspector in charge, have been detailed to the inspection of dairies and farms, milk shipping stations and creameries, in a vast area that for want of a better name we will call the "milk shed." In 18 months 37,178 Inspections were made, each inspection representing a farm, some located as far as 15 miles from the railroad.

The large territory from which our milk supply is drawn comprises many thousand square miles. There are 900 of such shipping points located in eight different states—Vermont, Massachusetts, Connecticut, New York, New Jersey, Pennsylvania, Maryland and Ohio, and lately milk is being shipped from Canada.

New York's great supply of milk is produced in varying sections with a corresponding variety of methods of production. The farms are located in eight states, which precludes the likelihood of uniform supervision by the various state governments. The gigantic problem of inspecting the cows, stables, milkers, utensils and water supplies used in producing this milk is therefore thrown upon the Department of Health of New York City.*

To be posted in all Dairies.

DEPARTMENT OF HEALTH

THE CITY OF NEW YORK

RULES AND REGULATIONS WHICH MUST BE OBSERVED BY FARMERS AND DAIRYMEN IN THE CARE OF COWS AND HANDLING OF MILK SHIPPED TO THE CITY OF NEW YORK

The Cows.

1. The cows must be kept clean.
2. Manure must not be permitted to collect upon the tail, sides, udder and belly of any milch cow.

Stables.

1. Cow stables must be well lighted and ventilated.
2. Floors must be tight and well drained.
3. Manure must be removed from the stalls and gutters before the morning milking and also before the afternoon milking, where the cows remain in the stable all day.
4. Walls and ceilings must be kept clean.
5. The ceilings must be so constructed that dust and dirt therefrom shall not readily fall to the floor or into the milk.
6. Stables must be whitewashed at least once a year.

The Water Supply.

1. The water used in the barn and for washing milk utensils must be free from contamination.

The Milk-House.

1. A milk-house must be provided, which is separated from the stable and dwelling house.
2. It must be kept clean and must not be used for any purpose except the handling of milk.

The Milkers.

1. No person having any communicable disease, or one caring for persons having such disease, must be allowed to handle the milk or milk utensils.
2. The hands of the milkers must be carefully washed immediately before milking.

The Utensils.

1. All milk utensils, including pails, cans, strainers and dippers, must be kept thoroughly clean and must be washed and scalded after each using.

The Milk.

1. Milk from diseased cows must not be shipped.
2. The milk must not be in any way adulterated.
3. The straining of milk must be done in the milk-house only.
4. All milk must be cooled to a temperature not above 55 degrees within two hours after being drawn, and kept thereafter below that, and must be cooled to 50 degrees or less if not delivered at the creamery twice daily.
5. The use of any preservative or coloring matter is an adulteration and its use by a producer or shipper will be a sufficient cause for the exclusion of his product from the City of New York.

RECOMMENDATIONS.

In addition to the preceding rules, the Department makes the following recommendations:

The Barn Yard.

1. It should be well drained and dry and should be as much sheltered as possible from the wind and cold.
2. Manure should not be allowed to collect in the barn yard and should not be at any time in contact with the stable or milk-house.

The Stable.

1. The cow stable should have an abundance of light and ventilation. The ventilation should preferably be from the top.
2. There should be at least 600 feet of air space for each cow.
3. It is desirable that the place where the cows are kept be used for no other purpose. A cow barn should not be used as a storage place for straw, hay or other feeds, or as a wagon or tool house, as the dust and dirt which accumulates in a place of this character is liable to drop into the milk while being drawn.
4. Stable floor should be made tight and be of some non-absorbent material.
5. Cement or brick floors are the best, as they can be more easily kept clean than wood or earth.
6. If the space over the cow is used for storage of hay, the ceiling should be made tight to prevent chaff and dust falling through.

The practice, somewhat common among farmers, of packing hay, etc., on loose poles over the cows is exceedingly bad, since it invites the collection of dust and cobwebs, and the difficulty of keeping the stable clean is increased.

7. The stable should be whitewashed twice a year.
8. The manure gutter should be from six to eight inches deep and should be kept free from manure.
9. The use of land plaster or lime is recommended upon the floors and gutters.
10. The flooring where the cows stand should be short enough so that all manure will be dropped into the gutter and not upon the floor itself.
11. The floor should be swept at least an hour before milking in order that the dust may have a chance to settle before the milking is begun.
12. If individual drinking basins are used for the cows they should be frequently drained and cleaned.

The Cows.

1. The cows should be kept at all times in a healthy condition, and an examination by a veterinary surgeon should be made twice a year.
2. The cows should be groomed daily and all collection of manure, mud or other filth should not be allowed to remain upon their flanks, sides, udders, or bellies during milking.
3. The clipping of long hairs from the udder and the right side of the cow is of assistance in preventing the collection of filth, which may drop into the milk.
4. The tails should be cut so that the brush should be well above the ground.
5. In winter the tail may be clipped.
6. The cows should be bedded with sawdust, shavings, dried leaves, straw or some equally clean material.
7. The use of horse manure for bedding is to be condemned.
8. To prevent the cows from lying down and getting dirty between cleaning and milking, a throat latch of rope or chain should be fastened across the stanchions under the cow's neck.

The Milking and Milkers.

1. The milkers should be clean.
2. Their hands should be thoroughly washed with soap and water and carefully dried on clean towels before milking.
3. Clean overalls and jumpers should be worn during the milking of the cows, should be used for no other purpose, and when not in use should be kept in a clean place protected from dust.
4. The hands and teats should be kept dry during milking.
5. The practice of moistening the hands with milk is to be condemned.
6. The first few streams from each teat should be rejected, as this contains more bacteria than the rest of the milk.
7. All milk drawn from the cows 30 days before and 10 days after calving should be rejected, and also all milk from diseased cows.
8. The pails in which the milk is drawn should have as small an opening at the top as can be used in milking. This renders the collection of dust less likely.
9. The milking should be done rapidly and quietly, and the cows should be treated kindly.
10. Dry fodder should not be fed to the cows during or just before milking, as dust therefrom will fall into the milk.

The Milk.

1. The milk should be removed as soon as drawn to the milk-house and strained and cooled to the proper temperature at once.
2. A good plan is to strain the milk into cans which are standing in ice water which reaches the neck of the can.
3. The more rapidly the milk is cooled the safer it is and the longer it will keep sweet.
4. Ice should be used in cooling as very few springs are cold enough for the purpose.
5. If aerators are used, they should stand where the air is free from dust or odor, and on no account should they be used in a stable.
6. Milk strainers should be kept exceedingly clean, and scalded a second time just before using, and if cloth strainers are used, several of them should be provided in order that they may be frequently changed during the straining of the milk.

FIG. 39.—DAIRY RULES— THESE AND OTHER RULES MAY BE HAD ON REQUEST.

It is, of course, understood that the Department of Health has no authority outside of the geographical limits of the city, but the Sanitary Code provides that "No milk shall be received, held, kept, offered for sale or delivered in the City of New York

*This "milk shed" has been divided into districts, to each of which an Inspector has been assigned and who is responsible for the character of the milk produced in that district.

without a permit from the Board of Health," and the Board can withhold or rescind this permit if unsanitary conditions exist at the dairy or creamery where the milk is produced or handled.

Rules and regulations for the production of sanitary milk are issued. These rules are printed on good muslin and cover all points relating to the sanitary conditions of the dairy and the

[illegible] 1907

Perfect Score [illegible] Allowed

File No. ....

DEPARTMENT OF HEALTH

CITY OF NEW YORK

Dairy Inspection **Division of Inspections**

1 Inspection No. .... Time .... A. P. M. Date 190
2 Tenant .... P. O. Address ....
3 Township .... County .... State ....
4 Owner .... Party Interviewed ....
5 Milk delivered at .... Since ....
Formerly delivered at ....
6 Creamery on .... R. R. .... Branch .... Miles to N. Y. ....
7 Creamery operated by .... Address ....
8 Distance of farm from creamery .... Occupied farm since ....
9 No. of Cows .... Breed .... No. Milking ....
Quarts milk produced ....
10 All persons in the households of those engaged in producing or handling milk are .... free from all infectious disease ....
11 Date and nature of last case on farm ....
12 A sample of the water supply on this farm taken for analysis .... 190 .... and found to be ....
13 Size of cow barn, length .... feet. Width .... feet. Height of ceiling ....

	Perfect	Allow
STABLE		
14 **COW STABLE** is .... located on elevated ground with no stagnant water, hog pen, or privy within 100 feet	1	
15 **FLOORS** are .... constructed of concrete or some non-absorbent material	1	
16 Floors are .... properly graded and water-tight	2	
17 **DROPS** are .... constructed of concrete, stone or some non-absorbent material	2	
18 Drops are .... water tight	2	
19 **FEEDING TROUGHS**, platforms or cribs are .... well lighted and clean	1	
20 **CEILING** is constructed of .... and is .... tight and dust proof	2	
21 Ceiling is .... free from hanging straw, dirt or cobwebs	1	
22 **NUMBER OF WINDOWS** .... total square feet .... which is .... sufficient	2	
23 Window panes are .... washed and kept clean	1	
24 **VENTILATION** consists of .... which is sufficient 3, fair 1, insufficient 0	3	
25 **AIR SPACE** is .... cubic feet per cow which is .... sufficient (1000 and over—3) (500 to 600—2) (400 to 500—1) (under 400—0)	3	
26 **INTERIOR** of stable painted or whitewashed on .... which is satisfactory 2, fair 1, never 0	2	
27 **WALLS AND LEDGES** are .... free from dirt, dust, manure or cobwebs	[illegible]	
28 **FLOORS AND PREMISES** are .... free from dirt, rubbish or decayed animal or vegetable matter	1	
29 **COW BEDS** are .... clean	1	
30 **LIVE STOCK**, other than cows are .... excluded from rooms in which milch cows are kept	2	
31 There is .... direct opening from barn into silo or grain pit	1	
32 **BEDDING** used is .... clean, dry and absorbent	1	
33 **SEPARATE BUILDING** is .... provided for cows when sick	1	
34 Separate quarters are .... provided for cows when calving	1	
35 **MANURE** is .... removed daily to at least 200 feet from the barn [illegible]	2	
36 Manure pile is .... so located that the cows cannot get at it	1	

FIG. 40.—DAIRY SCORE CARD—FRONT.

health of the cows and the milkers. A copy of these rules printed on linen is posted in every cow barn in the "milk shed." These rules are encouraging the production of sanitary milk and are making filthy and unclean methods the exception.

With the dairy rules posted, the next step is to see that they are enforced. An Inspector is assigned to a district, through which he moves in a systematic way. He first inspects a cream-

ery and ascertains its sanitary condition, and then inspects all dairies drawing to that station before passing to the next. Each inspection is complete in itself and all of the information obtained is tabulated on a score card and mailed to the office in New York. The Inspectors average ten inspections a day and they move from one district to another. With the present force, the entire territory is covered once a year.

37	LIQUID MATTER is .... absorbed and removed daily and .... allowed to overflow and saturate ground under or around cow barn	2	
38	RUNNING WATER supply for washing stables is .... located within building	1	
39	DAIRY RULES of the Department of Health are .... posted	1	
	COW YARD		
40	COW YARD is .... properly graded and drained	1	
41	Cow yard is .... clean, dry and free from manure	2	
	COWS		
42	COWS have .... been examined by Veterinarian .... Date .... 190.... Report was	3	
43	Cows have .... been tested by tuberculin, and all tuberculous cows removed	5	
44	Cows are .... all in good flesh and condition at time of inspection	2	
45	Cows are .... all free from clinging manure and dirt. (No. dirty ....)	4	
46	LONG HAIRS are .... kept short on belly, flanks, udder and tail	1	
47	UDDER AND TEATS of cows are .... thoroughly cleaned before milking	2	
48	ALL FEED is .... of good quality and all grain and coarse fodders are .... free from dirt and mould	1	
49	DISTILLERY waste or any substance in a state of fermentation or putrefaction is .... fed	1	
50	WATER SUPPLY for cows is .... unpolluted and plentiful	2	
	MILKERS AND MILKING		
51	ATTENDANTS are .... in good physical condition	1	
52	Special Milking Suits are .... used	1	
53	Clothing of milkers is .... clean	1	
54	Hands of milkers are .... washed clean before milking	1	
55	MILKING is .... done with dry hands	2	
56	FORE MILK or first few streams from each teat is .... discarded	2	
57	Milk is strained at .... and .... in clean atmosphere	1	
58	Milk strainer is .... clean	1	
59	MILK is .... cooled to below 50° F within two hours after milking and kept below 50° F until delivered to the creamery	3	
60	Milk from cows within 15 days before or 5 days after parturition is .... discarded	1	
	UTENSILS		
61	MILK PAILS have .... all seams soldered flush	1	
62	Milk pails are .... of the small mouthed design, top opening not exceeding 8 inches in diameter. Diameter	3	
63	Milk pails are .... rinsed with cold water immediately after using and washed clean with hot water and washing solution	2	
64	Drying racks are .... provided to expose milk pails to the sun	1	
	MILK HOUSE		
65	MILK HOUSE is .... located on elevated ground with no hog-pen, manure pile or privy within 100 feet	1	
66	Milk house has .... direct communication with .... building	1	
67	Milk house has .... sufficient light and ventilation	1	
68	Floor is .... properly graded and water-tight	1	
69	Milk house is .... free from dirt, rubbish and all material not used in the handling and storage of milk	1	
70	Milk house has .... running or still supply of pure clean water	1	
71	Ice is .... used for cooling milk and is cut from	1	
	WATER		
72	WATER SUPPLY for utensils is from a .... located .... feet deep and apparently is .... pure, wholesome and uncontaminated	5	
73	Is .... protected against flood or surface drainage	2	
74	There is .... privy or cesspool within 200 feet (........ feet) of source of water supply	2	
75	There is .... stable, barn-yard, or pile of manure or other source of contamination within 200 feet (........ feet) of source of water supply	1	
		100	

1587, '07, 60,000 (P) .... Inspector of Foods

FIG. 41.—DAIRY SCORE CARD—BACK.

This score card has 75 items and covers the entire condition of the dairy. Each item has a value so that every place is given a rating that at once shows its percentage and character.* A

*For two years prior to the establishment of the large Dairy Division, two experienced Inspectors investigated the conditions surrounding the production of the City's milk, defined the exact area of the milk district, and brought to light the vast number of abuses that prevented a clean and unpolluted supply. They made preliminary inspections in various creameries, skimming stations and cheese factories that sent their entire or surplus milk or cream to New York.

majority of the city milk dealers incorporate the rules and regulations in the contract they make with the farmers for their milk.*

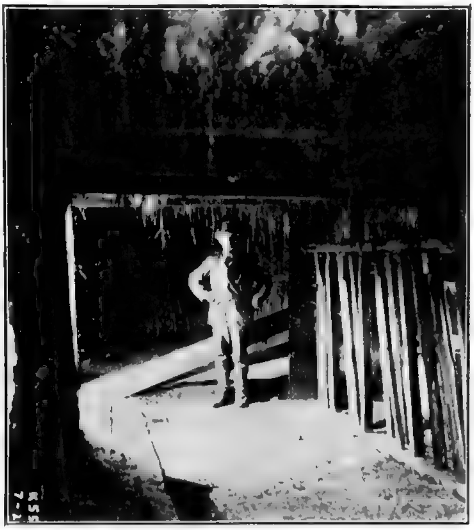

FIG. 42.—BAD BARN— NOTE HOW LITTLE THE MILKING IS PROTECTED FROM DUST AND DIRT FROM THE CEILING.

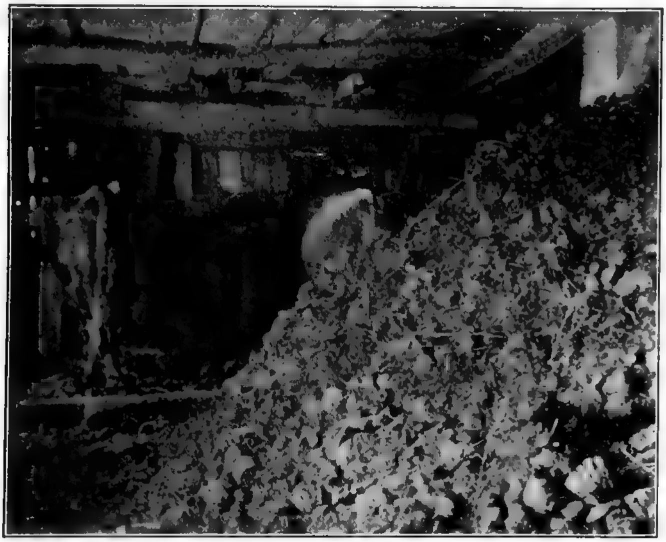

FIG. 43.—UNSIGHTLY AND OBJECTIONABLE MANURE PILE IN BARN.

*One of the largest up-State companies operating a number of creameries some years ago published a notice to the farmers stating that their published list

The very qualities which make milk an excellent and desirable food also render it undesirable from another standpoint. As it is a particularly good medium for the growth of bacteria, it is essential that milk must not be exposed to dust and filth, and the surroundings of its production should be of the best.

In some stables apparently no effort is made to remove the manure, with the result that the interior of the barn fast assumes the appearance of a manure pit. The inference is, when the interior of the barn becomes entirely filled, the farmer will move his cows out and build a new stable, and the process

FIG. 44.—COW STANDING IN MANURE IN THE BARN YARD.

will begin all over again. In the meantime the cows and milkers must wallow through this manure, scattering its stench and filth into the air and into the milk. Inspection improves these conditions.

A few of these dairies were closed, as the improvements demanded meant an entire rebuilding of the dairy. It was in a stable of this kind that the inspector saw a farmer, while

of prices apply only to those farmers whose premises have been scored 60 per cent. or higher by the Department of Health of New York City, those scoring less will have a reduced price, and milk from any dairyman whose premises score less than 50 per cent. is not desired and will not be accepted.

striking a cow, knock a quantity of manure into the milk pails, then calmly go, strain out the lumps of manure and send the milk to the creamery to be sent to New York. No amount of filtering or of pasteurization could ever make milk produced in such surroundings fit for human consumption. In fact, nothing can atone for filth. Preventive measures are better than corrective ones, and whatever opinion may be held as to the relative necessity of wholesale pasteurization, the essential feature of a pure milk supply is that the milk be produced under clean conditions and that it be kept clean.

FIG. 45.—DIRTY AND UNSIGHTLY DAIRY.

The rules concerning the cows provide that they must be kept clean and that the manure must not be permitted to collect upon the tail, sides, udder and belly. These rules, to the clean dairyman, would be recognized as an essential, but to the filthy dairyman an apparent impossibility and a hardship. Cows should be cleaned the same as a horse.

The old habit of using the barn as a storage place for dust-gathering material should not be, and is no longer, tolerated. A stable, to be a healthy place for a cow, must not only be roomy and well ventilated, but it should be clean, dry and free from rubbish. Stables with filthy walls and ceilings, where no effort is ever made to ventilate or furnish light, are not proper places in which to produce milk.

Foul and wet cow yards do their share of polluting milk,

by maintaining pools of stagnant liquid matter, covered with a green slime and scum, and piles of manure. Flies breed and

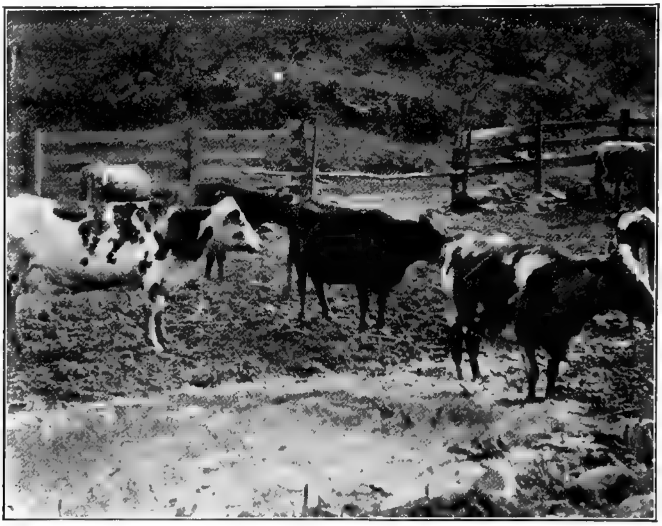

FIG. 46.—COW STANDING IN POOL IN THE BARN YARD.

thrive on the manure, solid and liquid, and they make frequent trips back and forth to whatever milk is handled or stored there.

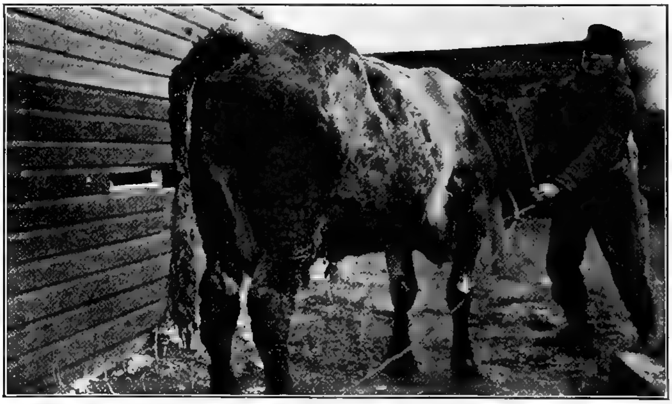

FIG. 47.—DRIED MANURE IN COW'S HAIR.

The filthy pool is reeking with danger and disease. The slime gets upon the udders and dries, to be later shaken into the milk.

No inconsiderable part of the work of the Department of Health is the investigation of the water supplies used in the various dairies. The Department of Health insists that the water

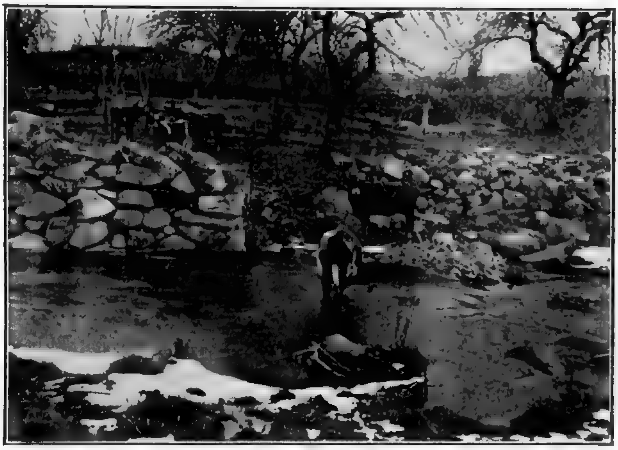

FIG. 48.—COWS WADING IN THEIR DRINKING WATER.

supply on the dairy farm must be pure. No dairyman should be allowed to use a supply that is otherwise. The inspectors have

FIG. 49.—PRIVY AND MILK UTENSILS IN CLOSE JUXTAPOSITION.

sent in thousands of samples of water, and the analysis of these samples, with the condemnation of impure supplies, has been a

lasting benefit to the dairyman in our milk shed and to the milk supply in general.

In the illustration we see a stable, dairy house, and privy clustered together, and in the center we see a well receiving its full share of filth and disease, transmitting in turn its filth and disease to the milk. A great many of the abuses here depicted have been largely corrected or improved.

Milk pails and cans should be exposed in the sun and in a clean atmosphere, and not exposed in the shade and within a few feet of a privy, between which flies can make frequent excursions.

It is wise to show the possible bad conditions surrounding the production of the milk supply and to warn the public of the dangers of unwholesome milk, but it would be unfair not

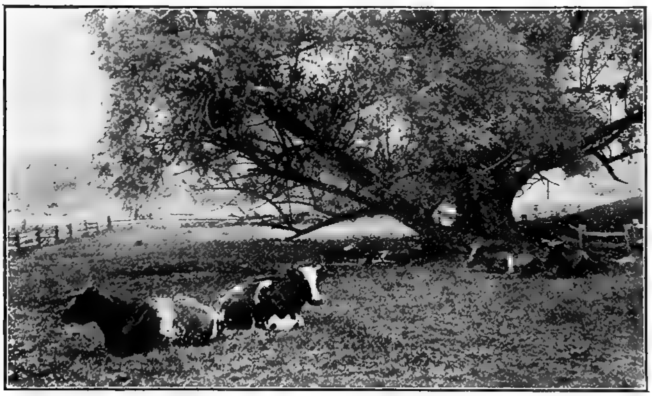

FIG. 50.—CLEAN, HAPPY COWS.

to tell of the very good, clean and wholesome places in which a great quantity of our milk is produced. A large percentage of our milk supply is now drawn from happy, normal and contented cows, which act as foster mothers to hundreds of children. In one large dairy barn where some of the best and purest milk is made, this sign is to be found: "Do unto a cow as you would that cow should do unto you; be kind and gentle."

Clean cows must be groomed, the long hairs must be clipped, and attention must be paid to keeping them clean. Manure is not so likely to adhere to short hairs, and the manure, if it should get on, is easily brushed off.

The effectiveness of the present system of dairy inspection is now being proved. Where re-inspections have been made, uniform improvements have been found. Whitewashing has invariably been done. Window lights and additional ventilation

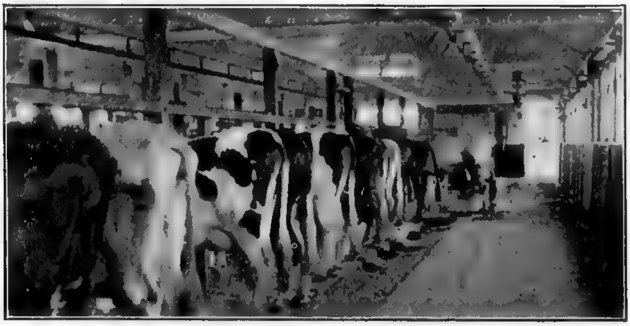

FIG. 51.—A GOOD BARN.

have been installed. A milk house has been built, huge piles of manure carted away, and the cow groomed and properly cared for. We have caused thousands of privies to be removed to a

FIG. 52.—GROOMING COWS IN GOOD BARN, BUT ONE CAPABLE OF IMPROVEMENT.

greater distance from the well, for the habit of farmers to install these two dangerous neighbors is well known. Barns old and of homely construction may be made absolutely sanitary.

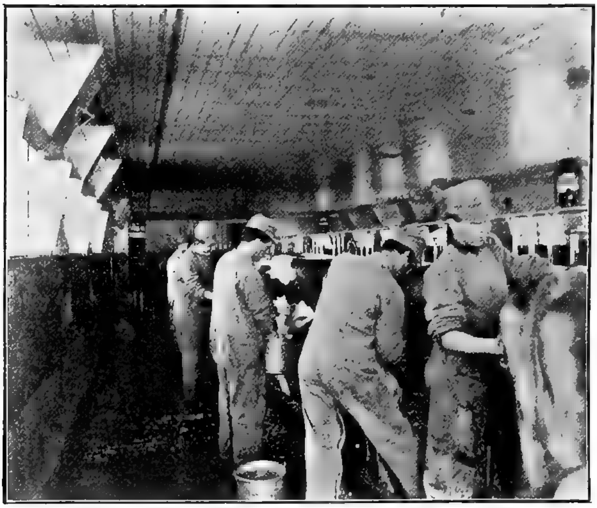

FIG. 53.

Before being milked, cows should be brushed and washed. A model barn, where milk is produced with every attention paid to cleanliness, is shown above. This stable is well built, has the King system of ventilation installed, and there are few places in the interior of this barn where dust may gather. The cows are examined regularly by a registered veterinarian, are groomed daily, fed clean and wholesome food, and the milking is done with every attention being paid to cleanliness. It is in a barn of this general type that certified milk is produced.

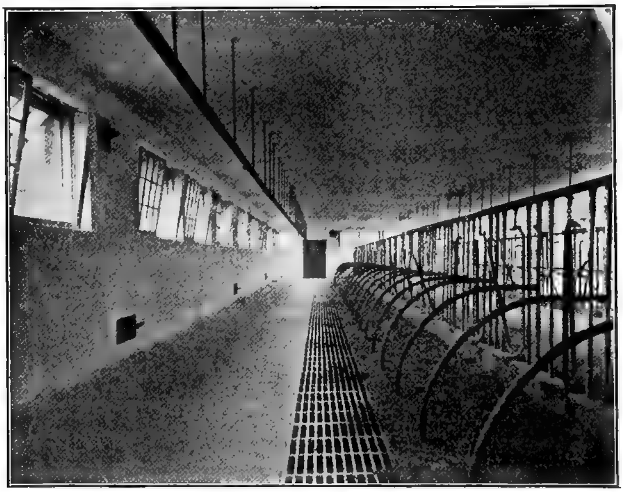

FIG. 54.

This is a dairy house located on the Walker-Gordon Farm at Plainsboro. This is where they produce and handle what is known as Modified Milk.

The new requirement that all cases of infectious diseases occurring in the households of the dairyman or his help must be reported at once, has had an educational effect upon the farmer, and has shown him how he can help stop the spread of milk-borne disease.

FIG. 55.—CLEAN MILKERS.

A group of milkers in a sanitary and clean dairy. It is easier to secure and hold help in a clean dairy than in a dirty one.

FIG. 56.—TYPES OF MILK PAILS. NARROW-TOP PAILS ARE BEST.

Certified milk means that the production and care of such milk has been certified to by a medical society of the county.* All Certified Farms score high on the Department of Health's requirements. When all the farmers who supply the city with

*In Manhattan Borough all certified milk bears the indorsement of the Milk Commission of the Medical Society, County of New York. In Brooklyn the Milk Commission of the Kings County Medical Society certifies such milk.

milk comply with the recommendation given them, the necessity of labeling any part of the supply "certified" will have disappeared.

FIG. 57.—CARTING TO CREAMERY.

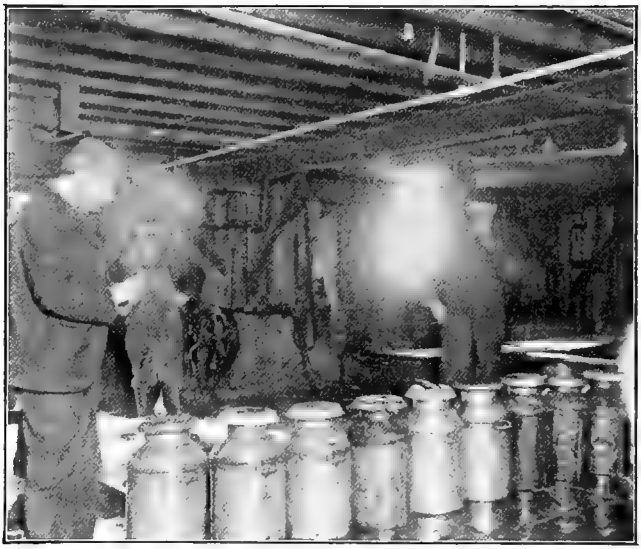

FIG. 58.—TESTING MILK IN A POOR CREAMERY.

Modified milk is pure cow's milk which is modified upon a doctor's prescription so as to closely resemble mother's milk.

This is done by the addition of cream and sugar or lime water, or whatever else is needed to adapt the milk to the requirement of a baby's stomach.

In the next link we find how the milk is being transported to the creamery in the typical old-fashioned open wagon with

DEPARTMENT OF HEALTH

THE CITY OF NEW YORK.

As a condition to the issuance of permits for the sale of Milk in The City of New York, all places where such milk is produced or handled must be open to inspection by employes of the Department of Health of The City of New York.

Rules and regulations which must be observed by those operating Creameries and Stations shipping Milk for use in New York City

The Buildings.

1. The floors of these buildings must be constructed of some material which will render them water-tight, and must be graded and drained towards one or more points from which water must be carried away by suitable drains. Floors of cement or stone are the best for this purpose.

2. The floors must be drained by water-tight gutters either into cesspools so situated as not to be offensive, or conducted to such a distance as not to cause a nuisance.

3. The water used for cleaning the pails, cans and other utensils must be from a public water supply, or, if drawn from a well or spring, must be approved by this Department.

4. The milk room must be used for no purpose other than the handling of milk, and must be clean and well ventilated.

5. Premises must at all times be free from a collection of water, rubbish or any offensive material.

6. Cooling tanks for milk must be tightly constructed of non-absorbing material and frequently cleaned. The water must be changed so frequently as not to become offensive.

7. Walls and ceilings must be kept clean.

8. Aerators and coolers must be protected from dust and from impure air.

The Employes.

1. No person suffering from a contagious disease or one in attendance upon such patient shall be employed in the handling of milk or milk utensils.

2. All employes who handle milk and milk utensils must be cleanly in their habits. The garments worn by such employes must be kept in a clean condition.

3. Spitting in or upon any part of the building must be absolutely prohibited.

The Milk.

1. Milk of a temperature above 60 degrees must not be received at the creamery or shipping station.

2. Milk must be handled as little as possible and all unnecessary exposure to the air must be avoided.

3. Milk must be rapidly cooled to a temperature of 50 degrees or less, and so kept until shipped.

4. All pipes through which milk is allowed to flow must be so arranged as to be easily and thoroughly cleaned.

5. All milk utensils, including cans and bottles, must be kept clean and sterile.

6. Managers of creameries and receiving stations will be expected to refuse to receive milk from farmers who do not observe the rules of this Department.

RECOMMENDATIONS.

1. In addition to the foregoing rules, the observance of which the Department of Health demands, the following recommendations in the construction of creameries and the handling of milk are presented:

A. Creameries should be well lighted. Ventilation should be ample, preferably through the roof.

B. Milk should be handled in rooms supplied with natural light.

C. Creameries should be so arranged that the milk may flow by gravity from the point where it is received to its final point of handling. Pumps, which are always difficult to keep clean, should never be used.

D. Outside dust should be prevented from entering the room where milk is handled, and flies should be excluded.

E. The rooms should be plastered or ceiled to avoid places where dust may gather

F. Frequent painting or whitewashing is strongly urged.

G. The receiving tanks, mixing vats, and tanks upon the bottling tables should be provided with covers.

FIG. 59.—CREAMERY RULES.

the farmer's son or hired man perched on top—the milk is covered with canvas to protect it from freezing in winter and from heat in summer.

The rules provide that milk shall be cooled by the farmer to within 50° F. within two hours after milking and kept below 60° F. until delivered to the creamery. As the milk is drawn at blood heat, it must be cooled, and kept in a spring or tank of ice water and protected.

In every creamery supplying New York City with milk we find the rules and regulations issued by the Department of Health. A great many unsanitary conditions and abuses have been found and corrected.

In the third link we find the creamery, the place where the milk is received from the farmer, where it is cooled, bottled and stored until train time. Each creamery is given its percentage on a score card. The 700 creameries that ship milk to New York are located on the various railroads running to New York.

175 F—1907

DEPARTMENT OF HEALTH
CITY OF NEW YORK

Perfect Score 100
Score Allowed ......%

DIVISION OF INSPECTIONS **CREAMERY CARD**

File.......... Inspection No. .... Time.......... A. P. M. Date.......... 190....
Location.......... P. O. Address..........
County.......... State..........
On.......... R. R. .... Branch.......... Miles to N. Y.
Owner.......... Address..........
Operator.......... Address..........
Manager.......... is.......... licensed. Number of help..........
All persons engaged in handling milk are .... free from any infectious disease. Number of patrons..........
Average Butter Fat test for dairies at present.......... Milk received daily.......... Lbs., Qts., Cans
Milk train leaves daily at.......... A. P. M. Arrives at.......... N. Y. Milk Platform
Method of Pasteurizing.......... Machine used..........
Cream is made by hand-skimming, separating.......... Living quarters are.......... located in Creamery
Butter, Cheese, Condensed Milk, Casein or Milk Sugar are.......... made on the premises
Car left for loading is.......... delivered cold. Cans are.......... wired or sealed before shipping

SHIPMENTS TO CUSTOMERS

Name..........	..........Cans	Pasteurized Milk	Marks..........
Address..........	..........Cases	" Cream	
Name..........	..........Cans	" Milk	Marks..........
Address..........	..........Cases	" Cream	
Name..........	..........Cans	" Milk	Marks..........
Address..........	..........Cases	" Cream	

FIG. 60.—CREAMERY CARD.

The largest milk carrying roads are the New York Central, Lackawanna, Ontario and Western, and Erie Railroads. One of the nearest creameries is at Turners, Orange County, New York, 52 miles out, and the farthest is in Ohio. Some milk comes from about 400 miles away.

As an instance of the way the orders of the Board of Health may be enforced, attention is directed to a creamery in the center of which was a well that received a great deal of the drainage from the imperfect floors, a condition that was immediately stopped upon discovery. This creamery attracted a great deal of notice a few years ago. The inspector found also

that a dangerous preservative was used regularly in this place, and to give the poor milk the rich, warm color of cream an injection of coloring was given each can; also all milk was skimmed and even the water used was from a polluted supply. From this creamery about 100 cans of milk were being shipped

	Perfect Score	Allowed
CREAMERY is ....located on dry and elevated ground	1	
Is ....at least 100 feet away from any hog-pen, privy-vault, factory manure loading platform or anything else objectionable	2	
Premises surrounding creamery are............clean	2	
RECEIVING ROOM is ....partitioned off from main milk room	1	
Air is ....free from dust, dirt or objectionable odors	2	
Weigh vats and storage tanks are............covered	2	
MILK HANDLING ROOM is............used exclusively for handling milk	1	
Is ....separate from where cans are washed	1	
Is ....separate from where engine or boiler is located	1	
Is ....well lighted by ....windows	2	
Has ....good ventilation	2	
All odors and steam from washing apparatus are............carried off	1	
WALLS AND CEILING are ....sheathed and dust tight	2	
Are ....painted with some light colored paint	1	
All ledges are............clean and free from dust and dirt	2	
FLOORS are............free from dirt, rubbish or pools of drainage	2	
Are ....made of concrete, stone or some non-absorbent material	4	
Are ....water tight	2	
Are ....so graded that all drainage is discharged at one or more points	2	
Strainers in floor are............at least 12 inches in diameter	1	
SPACE BENEATH CREAMERY is............dry	2	
Is ....free from waste or rubbish	1	
DRAINS are ....of earthenware or iron	2	
Are ....water-tight	2	
Are ....continuous from the floor level to point of disposal	2	
Are ....protected against freezing	1	
DRAINAGE is ....satisfactorily disposed of	5	
Discharged into a stream		
Discharged into a covered cesspool and pipes properly trapped		
Land disposal at least 500 feet away from creamery		
MILK PUMPS AND PIPES for milk, can ....be readily taken apart	1	
Are ....thoroughly cleaned daily	2	
All steam and water pipes are............painted and clean	1	
STORAGE TANKS OR MIXING VATS are ....in good repair	1	
All tin joints are ....soldered flush	1	
Are ....thoroughly cleaned daily	2	
MILK CANS are ....washed with hot water and washing solution	2	
Are ....rinsed out with clean water	1	
Are ....exposed to live steam for at least two minutes	2	
ALL MILK is ....protected from dust and dirt while in pools	1	
Is ....protected while in mixing vats or over aerators	2	
Is ....received at a temperature not above 60° F	2	
Is ....kept below 50° while held or handled on premises	2	
COOLING TANKS are............water tight	1	
Are ....made of some non-absorbent material	1	
Are ....supplied daily with clean water or filled with clean ice	1	
WATER SUPPLY is ample for all the needs of the creamery	5	
Water supply is ....apparently free from all contamination and is from	10	
ICE POND is ....polluted by privy or creamery waste	2	
STORAGE TANK for water is ....cleaned regularly	1	
Is ....covered or protected against dirt	1	
ATTENDANTS are ....cleanly in their habits	2	
Garments worn by such employees are ....clean	2	
PRIVY, water closet, earth closet, tight vault is ....satisfactorily located	2	
Is ....in a cleanly condition	1	
SPITTING OR SMOKING in any part of the building is ....allowed	2	
Remarks............		
	100	

.... Inspector of Foods

FIG. 61.—CREAMERY SCORE CARD.

This shows the number of items on a creamery card. When the various creameries were first inspected, many abuses were found and corrected. Many buildings unfitted from a sanitary standpoint for the handling of milk were condemned.

daily. The inspector saw this milk shipped to New York and followed it, and when it was loaded on the trucks, the inspector, having telegraphed ahead for a few police from the Sanitary Squad, had the truck stopped, and the entire supply of milk was condemned and turned into the sewer.

As good and bad conditions are found in the dairies, so good and bad conditions are found in the creameries. Bad con-

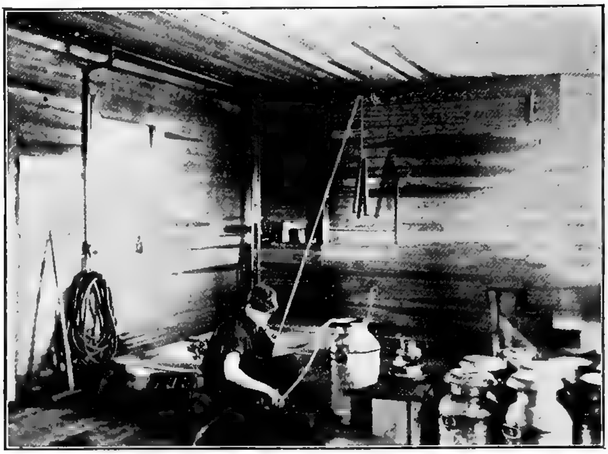

FIG. 62.

Here is a fair sample of wrong and dangerous methods found—a young man, filling milk bottles through a rubber hose, forming a syphon in the hose by sucking the milk through. The inspector stopped this practice at once. A very limited time was given to the owner of this creamery to have proper equipment for bottling milk installed.

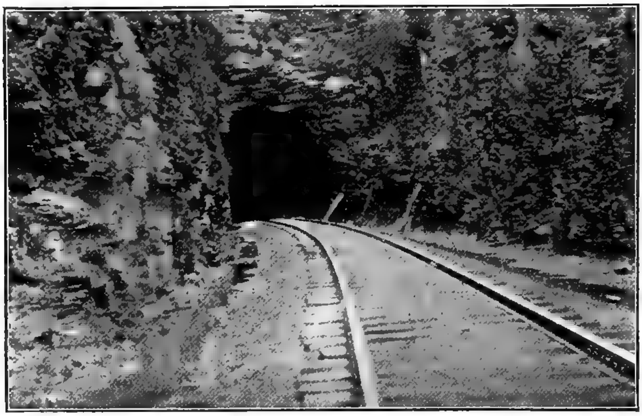

FIG. 63.

The water beside the tracks is from a spring located in the tunnel. At the time of inspection there was a gang of about fifty Italians working in this tunnel. This small stream was used as a sewer and also used as the water supply of a nearby creamery. Needless to say, this creamery shipped no milk the day this was found, nor was it allowed to ship any until a new and pure supply of water had been obtained and used.

ditions should be stopped or remedied and good conditions should

be endorsed and sometimes improved. A good creamery is well lighted and ventilated and is built in a sanitary manner. It is roomy and clean, and milk handled in such surroundings is normal and wholesome.

The milk in a sanitary creamery is bottled on clean tables, the bottles are sterilized, filled and packed in ice and put on the milk train. The interior construction is such that the floors, side walls and all equipment can stand the hose being turned on them and cleaned.

Some of the larger companies "clarify" the milk. This consists of passing all milk through a separator, an invention that has revolutionized dairying throughout the world. The sep-

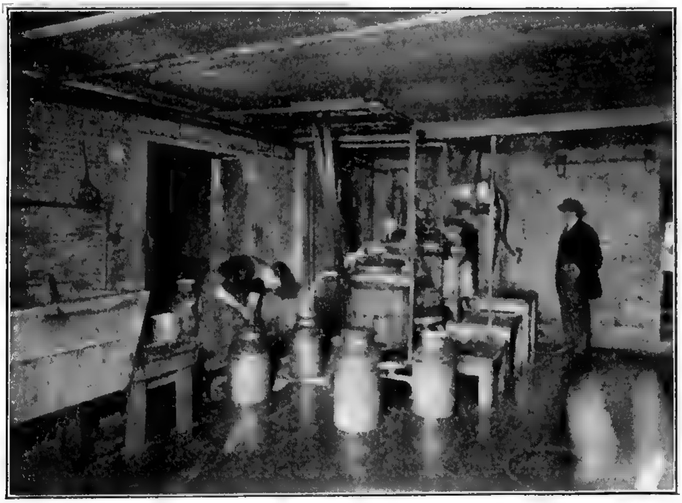

FIG. 64.—POORLY LIGHTED CREAMERY.

arator is a centrifugal machine, revolving at the high speed of over 2,000 revolutions a minute. The milk is hurtled around at this rapid pace, and the cream being the lighter is forced to the center and the top, and is there scooped off by a small pipe. The process is continuous. After the separation, the two parts are immediately remixed. The process of the separation removes nearly all the foreign matter from the milk.

The aeration of milk simply means that it has been properly and quickly cooled. This is accomplished by an arrangement

of coils through which ice water is pumped and over which the warm milk flows in a thin sheet. The milk is exposed to the

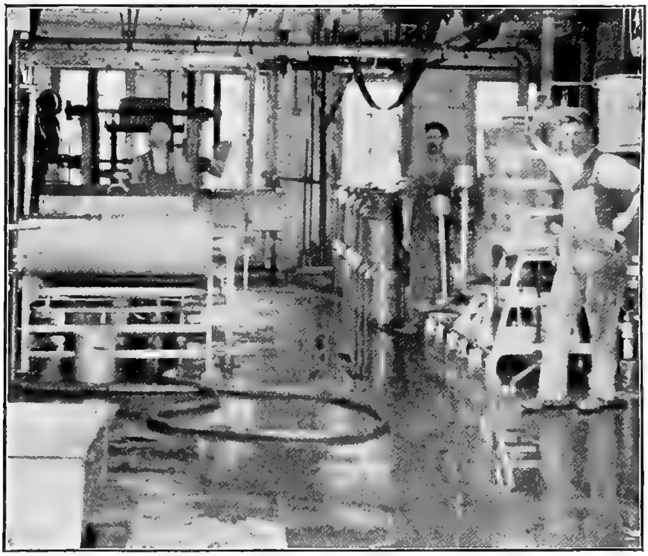

FIG. 65.—A WELL LIGHTED CREAMERY, WHICH MAY EASILY BE WASHED OUT BY MEANS OF HOSE.

FIG. 66.—INSPECTION IN CARS.

The interior of one of the cars is here shown. The milk is packed solid, allowing only room in the center to open the doors.

air, and some milkmen advertise "aerated milk" as if it were

something special, which it no doubt is to those who do not know.

Link number four is the milk train. These trains start from Alleghany or St. Lawrence County or wherever else at the far end of a railroad early in the morning, stopping at station after station until the cars are loaded, then, running on express time, they reach New York in time to meet the milk trucks at 11 p. m. at the terminals. An inspector tests the milk while the train is on its way to the city.

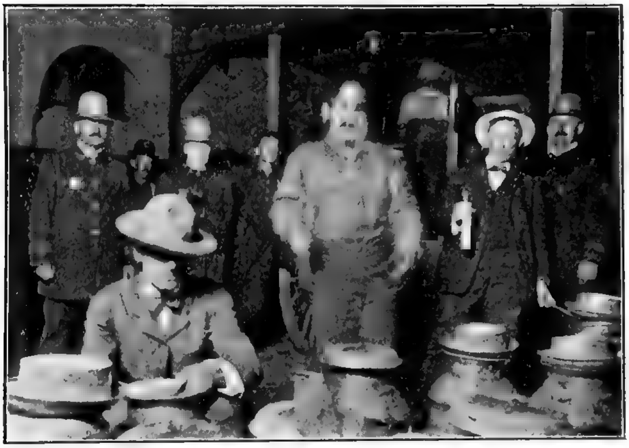

FIG. 67.

City Milk Inspector with his escort of Sanitary Policemen, rapidly going from can to can to detect adulterated milk.

In link number five we find the milk platform, one of the busiest places in New York City from 9 o'clock at night till 5 o'clock the next morning. The average city man hardly notices the caravan of trucks that nightly wend their way to the ferries. An army of men toil as others sleep. Rapid and hard work is done to furnish a goodly supply to the City of New York when it wakes up in the morning, and, like a gigantic baby, cries for its milk. In summer quick work has to be done in taking away the milk on trucks, as the milk will soon warm up and sour if kept long exposed. The cars are loaded again with empties, so that the train can start back to the country within two or three hours.

It is at this link where the City Division of Milk Inspection appears. In New York there are 20 inspectors, with one in

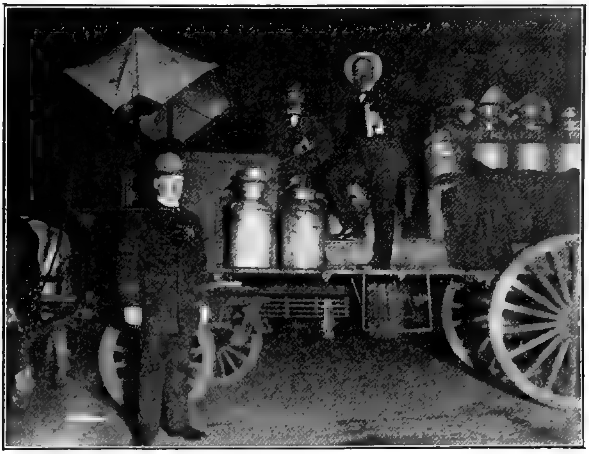

FIG. 68.

Sometimes the milk inspector waits until the milk is loaded on the wagons. Then his work is a little more difficult.

As the night advances and daylight breaks, we find the inspector stopping large and small trucks alike, and passing through the milkman's load of milk, seeking to detect bad milk. Many a driver protests at the delay, for this is no excuse to the householder who wants his milk when he wants it.

If the inspector finds any adulterated milk, a proper sample is taken and the milk is destroyed.

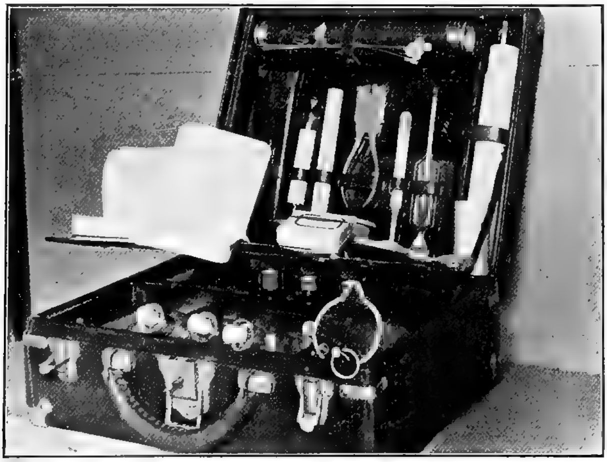

FIG. 69.

The milk inspector's outfit is a rather large one, consisting of telescopic dipper, lactometer, thermometer, electric flash-lamp, bottles and seals for taking the samples.

charge, whose duty it is to see that all milk offered for sale is of good quality.

The inspector carries books of record and gives a duplicate sample to the milk dealer, so that the dealer himself can have his own milk analyzed to see if it agrees with the analysis made by the Department. The milk inspectors each morning take their samples of milk to the laboratory, where they are analyzed. With sometimes as high as a hundred samples being presented in a day, the chemist and his assistants are kept busy. It is upon their testimony as to the character of the milk that the prosecutions of the Department are made.*

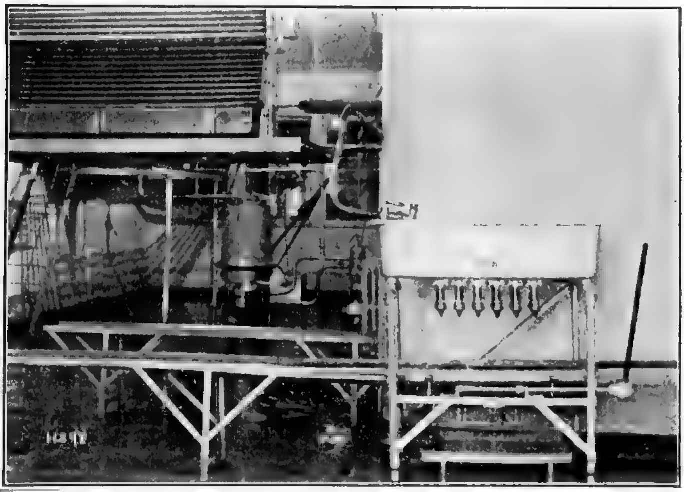

FIG. 70.—CITY BOTTLING PLANT.

The Sanitary Code defines adulterated milk as follows:

"Milk containing more than eighty-eight per centum of water or fluids, less than twelve per centum of milk, less than three per centum of fats.

"Milk drawn from animals within fifteen days before or five days after parturition, or from animals fed on distillery waste, or any substances in a state of fermentation or putrefaction, or any unwholesome food, or drawn from cows kept in a crowded or unhealthy condition.

*Milk is analyzed by first being tested by the Babcock test. This consists of adding sulphuric acid to a small amount of milk. This acid dissolves the solids other than fat. Then the mixture in a bottle is whirled rapidly around in a Babcock centrifugal machine until the butter-fat is thrown to the center, where, in the neck of the same bottle, it is seen and registered. Then follow a weighing of the various solids of the milk and tests for borax, formaldehyde, or other preservatives.

"Milk from which any part of the cream has been removed, which has been diluted with water or any other fluid, or to which has been added or into which has been introduced any foreign substance whatever, or milk the temperature of which is higher than 50° Fahrenheit."

If the chemist finds any milk testing below 3 per cent. butter-fat or 12 per cent. total solids, the matter is placed in the hands of the Assistant Corporation Counsel, who is the prosecuting attorney for the Department. A warrant is issued for the dealer or vender of the milk and one more case is added to the calendar of Special Sessions, where every Monday morning milk cases are tried.*

FIG. 71.—SELLING MILK ON STREET.

When the public see milk sold on the sidewalk exposed to every whirling gust of dried sputum or manure, they should refuse to accept it.

Classed in this link is the City Milk Bottling Plant. Some of the large dealers are bottling all their milk in the country; others are shipping it into the city in cans, pasteurizing it and bottling it, as in this type of City Milk Depot. There are advantages in both methods. The best method from the public standpoint is to have it bottled in the country. The best method from the dealer's standpoint is to have it bottled in the city. In city bottling the milk is nearly always 24 hours older, and, to keep it from souring, it is generally pasteurized.

Some mention should be made concerning pasteurization. This is a process named after the famous Frenchman, Louis Pas-

*During 1906, 41,395 quarts of adulterated milk were destroyed, 678 arrests were made and $13,045.00 were collected in fines from dealers and venders of impure milk; the judges are now showing an inclination to send frequent offenders to jail without the alternative of a fine.

teur, and depends upon heating milk to 155° F. for about 30 minutes. If done properly, the treatment destroys all bacteria and no doubt prevents any form of disease from being transmitted through the milk. The majority of pasteurized milk offered to the public is heated to 155° F. for only 15 to 25 seconds. If you are using pasteurized milk, I can only suggest that you use it the same day you receive it, for old pasteurized milk is generally more dangerous than old raw milk. When raw milk is old, nature provides a warning in the increase of lactic acid

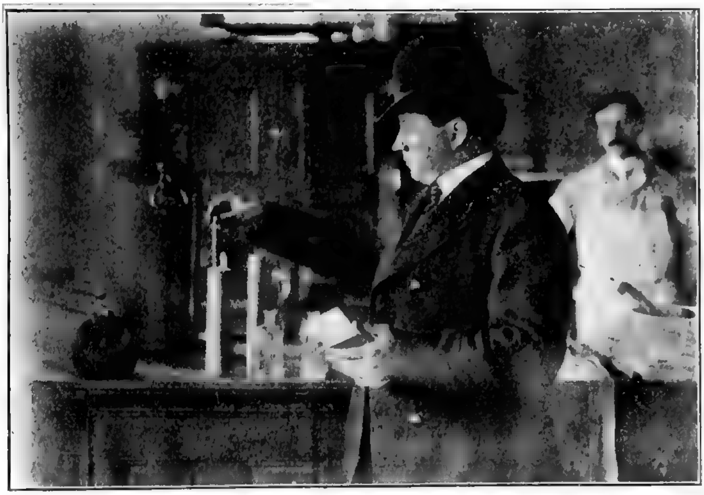

FIG. 72.—TESTING MILK IN STORE.

and it becomes sour. The warning is absent in pasteurized milk, which has a tendency to putrefy instead of sour.

In the sixth link is the retail store. Here is a type of store that should not sell milk, since milk with its absorbent qualities is often exposed to contamination. Here is where the public must show discrimination and judgment.

In the store is where the milk inspector has his hardest duty to perform. The entire city has to be covered, and there are over 12,000 places where milk is offered for sale. A great many of these stores are on the East Side, where tastes are so diversified, for the East Side population is a cosmopolitan one. As an illustration of this, it may be mentioned that there are

news-stands with five daily papers offered for sale in five different languages. Yet this great, oddly mated population needs pure milk, and the Department of Health must see that it gets it.

In the better class of store, while inspection does not have to be so frequent, it should nevertheless be performed with regularity. The time is not far distant when milk will be sold exclusively in the Dairy Stores, where the attendants are in white suits and dispense the milk in sterile bottles on marble slabs, where everything will be hygienic and scrupulously clean. It is a condition that must come.

FIG. 73.—INSPECTOR IN A DECENT DAIRY STORE.

Link number seven is milk in the home. An essential feature of a comprehensive plan for reducing infant mortality is the education of the mothers of the poor in the proper methods of caring for, bathing and feeding their infants. They need to be taught domestic cleanliness, the proper care of milk, and the principles of infant hygiene. There is much ignorance in such matters. The Department of Health must educate and help. Through its trained nurses and physicians it tries to have the uneducated understand the nature of milk and how to feed it properly. So during the hot summer months, the nurses go from door to door, instructing mothers how best to care for their babies. The economic necessity for this work is growing more urgent every year.

After the milk reaches the home, the responsibility of the individual is at its hight, and until the time comes when the public does demand pure milk and sees that it gets it, unscrupulous dealers will thrive. Every housewife should see that dirty milk is not delivered.

DEPARTMENT OF HEALTH

CITY OF NEW YORK

NOTICE TO THOSE WHO USE MILK

You are requested to report at once to the DEPARTMENT OF HEALTH any violation of the following rules and regulations for the care and sale of milk.

Telephone Number is 4900 COLUMBUS.

MILK MUST BE KEPT COLD AT ALL TIMES.

WARM, DIRTY, SOUR or ADULTERATED MILK must not be sold.

All CANS, BOTTLES, DIPPERS, etc., must be CLEAN, and kept clean.

CANS containing MILK must be kept in a CLEAN ICE TUB or REFRIGERATOR.

MILK must not be kept OUTSIDE THE STORE.

MILK must be so COVERED that no DUST or DIRT can fall into it.

MILK must not be kept in ANY ROOM connected with STABLES OR LIVING APARTMENTS, nor in ANY ROOM connected with WATER CLOSETS that are not properly ventilated or vestibuled.

MILK must not be kept in A ROOM which is DARK, DIRTY or POORLY VENTILATED, or where there are BAD ODORS.

NO PERSON who has a CONTAGIOUS DISEASE, or who comes in contact with a person having a contagious disease, will be allowed to HANDLE MILK.

THESE RULES are adopted by the BOARD OF HEALTH for the purpose of obtaining good, clean, safe milk for the people of this City, and all permits for the sale of milk are granted on the conditions that these rules will be followed. If the rules are violated, the permits may be revoked.

BY ORDER OF THE BOARD OF HEALTH

EUGENE W. SCHEFFER, Secretary   THOMAS DARLINGTON, M. D., President

TO BE POSTED IN A CONSPICUOUS PLACE IN ALL STORES WHERE MILK IS SOLD.

FIG. 74.—DIRECTIONS TO THOSE WHO USE MILK, ISSUED BY THE BOARD OF HEALTH.

Practical Home Methods for Testing Milk.

There are three ways to test milk in the home. To test its freshness, bring it to a boiling point. If it curdles, it is old. To test for richness, let the cream rise; 14 per cent. cream should be found. To test for bacteria, let it stand for two hours; if there is sediment in the bottom of the bottle, discard it as dirty. Milk with sediment in the bottom of the bottle should not be bought

or used. In fact, of all the household tests that it is possible to apply to milk, the one of dirt is alone unfailing.

The work in milk is but a part of the great change that is taking place throughout the country and of the effort made for the relief of physical suffering, for the prolongation of life, and for health and happiness. All of the sanitary laws of our land are founded on one old law, "Thou shall love thy neighbor as thyself." The man that loves his neighbor will not sell unclean or adulterated milk. It is a warfare against ignorance, prejudice, neglect and poverty. In milk it is largely a matter of ignorance. For I fully believe that if the farmer knew that when he did not scald his pail and did not wash his hands he was the cause of the death of a child in the city, I believe that he would do so. It is therefore largely a matter of education.

CHAPTER VI

The Purpose, Method and Extent of Food Adulteration.

HARVEY WASHINGTON WILEY, M.D., Ph.D., LL.D.,
Chief, Bureau of Chemistry, United States Department of Agriculture, Washington, D. C.

The practice of food adulteration is almost, if not quite, as old as history. Food, like air, must be had all the time in order to sustain human life. The only difference is that, deprived of air a man dies in a few minutes; while if deprived of food, he may live a few days, or even a few weeks in extreme cases.

Fortunately no one has ever been able to get a monopoly of air—although the air has been adulterated—not, however, with the object of making it cheaper or debasing its character. On the contrary, food must be worked for, paid for, or surreptitiously obtained, and hence many attempts have been made from the earliest times to debase its quality, to add injurious substances to it, and to disguise its labels. Therefore, the purpose of food adulteration is easily apparent. So far as I know, its sole purpose is illegitimate gain.

The man who produces food, the man who prepares food, the man who transports food, and the man who sells food, is each entitled to a fair profit for his labors. Especially the farmer, who produces the food, should not be neglected, but just as important is the charge rendered by the man who prepares the food, the man who transports it, and the man who sells it. Hence the price to the ultimate consumer is not only the cost of production, the cost of preparation, and the cost of transportation, but in addition to this a legitimate profit for each of these steps.

In general it may be said, when left to the legitimate laws of supply and demand, that the price of food will vary in proportion as the cost of production, preparation and transportation varies, assuming that the profits remain practically the same.

Various methods, however, have been devised to increase the profits. Competition regulates to a large extent these profits. The more farmers there are in competition, other things being equal, the less profit each one will secure. The more utilities of preparation, other things being equal, the less any one preparer of foods will secure as a profit. The more lines of transportation, other things being equal, the less the cost of transportation and the less the profit to the transportation companies. The more depots of distribution, other things being equal, the less the profit which any one distributor will secure. It is evident that competition may be of such a character as to entirely eliminate the margin of profit in all these lines and even cause a food product to be offered to the consumer at less than the actual cost thereof.

With this problem, however, food adulteration does not have to deal. It has to deal, first, with the purpose of its practice. It is evident without argument that a food product of a superior quality may be debased without changing its aspect or its name, and, in so far as ordinary trial can be made, without apparently changing its nutritive value. If this can be done, it follows as a logical sequence that this product will obtain the same price on the market as the genuine article; hence, the purpose of that species of food adulteration which debases the article. An illustration of this, and a very simple one, is the removal of cream from milk, or the addition of water thereto. Each of these practices can be indulged in to a certain extent without destroying the appearance, or character, or apparent nutritive properties of the milk. Such milk can therefore enter commerce and secure the price of the genuine article. The amount of increased profit is exactly equal to the degree of debasement practiced.

Again, food products are often judged largely by their color. A cream, for instance, is supposed to be yellow, and a strawberry red, and an old liquor a yellow-red color. It is evident, therefore, that if a cream which contains a small amount of butter fat can be artificially colored, it may seem to be very much richer than it actually is; and if strawberry preserves, which may lose their color on keeping, may be artificially colored, they look fresher than they are; and if a freshly distilled

product can have the color of age simulated by the addition of caramel, it will apparently have a virtue which it does not really possess. Hence, the use of coloring agents for fraudulent purposes permits the introduction into commerce of articles which, by this artificial coloring, bring a higher price than they otherwise would.

Another important illustration of this principle is in the opposite direction, where the presence of color is supposed to be a mark of inferiority, whether it really is or not. Hence, a white flour is adjudged by most people to be superior to one of a gentle yellow color, and this has caused the introduction to a very large extent of artificial bleaching (secured by the use of peroxide of nitrogen), which discharges its color and makes a yellow flour look white. In this way, lower grades of flour, as regards color, are bleached in order to resemble the higher grades, and mixtures are sold as of higher grade to the prejudice of the consumer. Hence, the purpose of the addition of color or its abstraction is to illegitimately increase profits.

There are still other kinds of food products which rapidly deteriorate and therefore bring on the market a lower price than when fresh. Various methods have been devised to keep such products in as fresh a state as possible, and most of these methods are perfectly legitimate if the consumer is informed that they have been practiced.

In most cases the appearance and flavor of the body itself give the information desired. This is true in the preservation of meat, where the appearance of the meat, its flavor and odor, all inform the consumer of the condition of the material.

Again, desiccation will enable a food product to be kept in a state suitable for consumption which would not keep if it retained its natural supply of water. The appearance of a desiccated product, however, is such that the consumer always understands the nature of the preservative process used.

It is also found that sterilization of perishable food products and the exclusion of fermenting germs therefrom is a most excellent method of keeping the product. This method, too, discloses itself to the consumer because such products are kept in closed vessels, to which the air has no entrance.

And last of all, cold storage is a most excellent and unobjectionable method of preserving foods.

All of these methods are to be commended and their use encouraged just in so far as the food can be kept in a state fit for consumption and just in so far as the practice of these methods of conservation are not used artificially to increase prices by withdrawing large quantities of perishable food products from the markets. This, however, is not always the case, as, for instance, in the spring, when eggs are cheap, the demand for eggs to be put in cold storage is such that the prices which otherwise would obtain to the consumer are kept on a much higher plane, more so perhaps than is compensated for by the lower price of eggs during the scarce season. But aside from this, all these methods of preserving have legitimate uses.

There is one method of preserving used which, it appears to me, has no excuse whatever, and that is the addition of poisonous or deleterious substances which destroy or paralyze the activities which produce decay. Whatever the nature of the antiseptic may be, it must paralyze or kill the germs before it because it is said that in the small quantities which are used, no matter what its name may be, must be a poisonous or deleterious substance. The use of such materials has been excused because it is said that in the small quantities which are used, no harmful effects are produced upon human health. The evidence, however, to support this is of a negative character, while, on the other hand, there is abundant evidence of a positive character to the contrary. The protection of the public demands, to my mind, the entire exclusion of chemical antiseptics in food products.

Often it is charged that these bodies are no more injurious than condimental substances, such as acetic acid. The futility of this claim is seen in that in the only form in which it occurs, vinegar, it is wholly burned in the body, converted into heat and energy, and in itself is a food as well as a condiment. Professor Van Noorden, the most celebrated authority on kidney diseases in the world, particularly permits the use of vinegar to his patients, when they crave it, on the ground that it is not only harmless but in itself a useful substance.

It follows, therefore, as the natural conclusion from these facts, that the addition of deleterious substances to food is never permissible. At the same time, I am not one of those who would deny to the consumer the privilege of using any one of these bodies if he sees fit to do so; but he should only have that privilege for himself and not insist upon it for another.

The purpose of this form of adulteration is also illegitimate gain because the preservation of foods by chemical antiseptics is by far less expensive than any other form of preserving which is employed. Hence, food products thus preserved can go into the market with those preserved in other ways and secure a higher profit to their manufacturers and distributors than otherwise would be the case.

In the above resumé of food adulteration I have also included many of its methods, so that the second part of the subject is largely discussed, necessarily, in the exposition of the first part.

The methods of food adulterations, to summarize them, are as follows:

1. The abstraction of some valuable ingredient of the product.
2. The addition of a less valuable ingredient.
3. The addition of an ingredient which serves largely as a filler and has practically no food value at all.
4. The mixing, or powdering, or grinding of a body whereby its inferiority is concealed.
5. The coloring of an article whereby inferiority is concealed.
6. The addition to a food product of a harmful or deleterious substance, which, in the language of the Food and Drugs Act, may render the article injurious to health.

The above comprise practically all the methods of food adulteration which are practiced. With the practicing of these methods, however, and as a necessary condition to their success, goes the practice of misbranding, which in itself may be considered an adulteration.

An authority very eminent in such matters, the late Professor A. B. Prescott, of the University of Michigan, stated in evidence before a Congressional committee that in his opinion

every form of adulteration was injurious to health, that the changing of any natural food product in any way by the withdrawing of any of its ingredients or the addition of even apparently harmless substances must of necessity injure health because it must be, of necessity, disturbing to the normal dietary.

There is a great deal of truth, I think, in Professor Prescott's contention. It may be claimed by a manufacturer that ground peanut shells are harmless substances. That may be to an animal whose organism is suited to digest a ground peanut hull, but man is not an animal of that kind. The pouring into a man's stomach of a considerable quantity of ground peanut hulls may result in serious injury, although there is nothing poisonous or deleterious in the peanut hulls themselves, and some animals might eat them with profit and convenience. And what may be said of a simple, debasing practice like this is more or less true of every kind that is used; hence, we may say that in the adulteration of food in the manner which has been described above very grave injury may come other than by the addition of poisonous or deleterious ingredients, but by the addition of substances which are not in themselves poisonous or deleterious.

The question may well be asked: "What are some of these poisonous or deleterious substances which are used?" The answer is a very simple one—the same kind of material is not used in all countries. When bodies of this kind are used in a country, and it becomes known, the legislature is very apt to enact laws against it. Then the people who desire to use these bodies are forced to use other bodies. Salicylic acid is one of the most efficient and, in my opinion, one of the least harmful of adulterants of this kind which has been used, and it was one of the first used. Nearly every country, however, has forbidden or restricted the use of salicylic acid, until now it is rare to find it in any food product in the United States. Legislation is directed against it from all quarters.

The same is true of formaldehyde, which is the ideal preservative for milk. It is forbidden in almost all countries and is rarely found in this country. Boron compounds were often used in the United States before the passage of the pure food law

to a considerable extent. At present the use of these compounds as a food preservative has almost ceased.

The principal preservative which is now used is benzoic acid or benzoate of soda. Some of the States have forbidden the use of these compounds in food products, while others tolerate them. The United States Government expressly permits their use in unrestricted quantities, but with the proviso that their presence be declared upon the label.

The third point is the extent of food adulteration. It is already seen that it is quite impossible to separate the three problems of this subject. In the above resumé of the methods of food adulterations I have also largely touched upon the extent of their use.

As indicated, this extent varies in different countries. The most extensive adulteration of foods by chemical preservatives at the present time is in Great Britain. The peculiar situation of Great Britain has led it to be particularly conservative in its legislation against antiseptics. Antiseptics are permitted freely in certain forms of foods manufactured and consumed in Great Britain.

Among those permitted may be mentioned boron compounds, which are allowed in meat and butter and in cream to the extent of from ¼ to ½ per cent. Salicylic acid is also permitted in foods in Great Britain in quantities not exceeding one grain per pound. Benzoic acid is not very extensively used in Great Britain, but probably would be subjected to about the same restrictions as are applied to salicylic acid.

In Germany the laws against the addition of deleterious ingredients in foods are more severe. Boron compounds are prohibited entirely. Benzoic acid and benzoate of soda have never been used to a very large extent in Germany. Salicylic acid is prohibited, and so is formaldehyde. Sulphurous acid is allowed in small quantities in dried fruits and in wines.

In France the laws against antiseptics are also quite restrictive. Salicylic acid, benzoate of soda, formaldehyde and boron compounds are prohibited. Sulphurous acid is permitted in wine, not to exceed 350 milligrams per kilogram. Sulphate of copper is permitted, not so much as a preservative as a coloring agent, in certain green vegetables, as peas, beans and spinach.

In the United States I have already indicated what are permitted. In all these countries, however, the use of antiseptics in strictly fresh foods is not practiced to any great extent. The other forms of adulteration, such as debasement in the way of the abstraction or addition of substances, are strictly forbidden by law and are only practiced surreptitiously until they are condemned by the courts. Excessive use over the prescribed amounts is also severely punished in all the countries named.

As a whole, it may be said that the practice of food adulteration is being gradually restricted in all countries, and certainly in the United States, where the amount of adulteration in any form is far less than at the time the Food and Drugs Act became a law. While there is still much to be done before securing an ideal food supply, we may be greatly encouraged by reason of the progress already made.

It may be asked if the restriction of food adulteration will not raise the price of food. To this I think the answer is undoubtedly in the negative. It is true that when various foods are relieved from competition with adulterated foods, they will have a fairer and freer market and will bring a legitimate price subject to the laws of supply and demand. On the other hand, lower grades of food can be produced without any adulteration at all and offered to a different class of consumers at a decidedly lower price than they have ever paid before. The result, it seems to me, will be beneficial both to the well-to-do consumer and to those who are in restricted circumstances. I do not believe, therefore, that any increase in the price of food can be properly laid to the fact of the restriction of adulteration and the requirements of the law for a proper branding of all foods. If, however, that should be the fact, even then there would be no reason to repeal these Acts, which have been doing so much to secure a better food supply for the public and so much to raise the moral tone of commerce in foods.

CHAPTER VII

THE REMEDY FOR FOOD ADULTERATION AND RELATION OF CHEMISTRY THERETO.

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Having in the previous lecture described the purposes, the methods and the extent of food adulteration, we may now consider the remedy for the evils and the relations of chemistry to this work.

It is evident, it seems to me, that the very best remedy for the evils of food adulteration would be the creation of a public opinion of a character which would regard persons engaged in food adulteration as without the pale of ethical, moral and polite society. As long as food adulterators occupy high social and official positions and receive recognition from what is known as the best element of society, you cannot expect that the profession of adulterating food will be looked upon as unworthy of pursuit. The fact of the case is that the manipulation of our foods, although offending every ethical and moral principle, althought depriving the consumer of his money, and although often injuring his health, has never been classed, at least in public estimation, with the same sort of offenses known under other names. The man who defrauds in any way, who obtains money under any kind of false pretence, or who imposes upon the confidence of the community by misrepresentation and falsehood, has never been regarded as a desirable citizen. It is, however, true that persons who are convicted of crimes of this kind in foods and drugs do not lose their standing in society and are not regarded in any ordinary sense as criminals. They do not even need to have the courage of their conviction, as a conviction for a crime of this kind does not attach, in the public estimation, any opprobrium to the name of the convicted. The case is not unusual of a person convicted of a crime of this kind

who not only continues in the highest business circles, but is placed subsequently in a high position of trust and profit by his fellow citizens. This would not be the case of a man convicted for the same crime known under another name.

The most important of the remedies, therefore, for food adulteration is the creation of a public opinion which will look upon it and upon its perpetrator with disfavor. To that end, it seems to me, the education of the community respecting the nature of food adulteration is of the highest importance. That education should begin in our schools and be continued in our colleges. In the family, in the school, and in the college the young man, or the young woman, receives those impressions which guide to a large extent his, or her, moral as well as financial career. I should like to see taught in the public schools the ordinary ways of food adulteration, the purpose of practicing it, and the simple remedies for its prevention and cure. This is already done to a certain extent. The laws of some States and municipalities require the teaching of certain principles of physiology or the inculcation of certain facts derived from these principles in regard to habits. For instance, the children in our public schools are shown the dangers and undesirability of the tobacco habit and the alcohol habit, and to a certain extent of the caffeine habit. The laws of some of the States and municipalities refuse the privilege of selling to a minor cigarettes, or distilled or fermented beverages. It seems to me that laws of this kind are wise and desirable. It remains to be demonstrated, in my opinion, that the use of tobacco or of caffeine, or of alcohol is of benefit to a child or a grown person. On the contrary, it is fraught with considerable danger in that there are many persons of weak wills or with certain appetites, who, with access to these things, early form the habit of their use which later becomes a curse to themselves and their friends. To my mind, therefore, it would be well in teaching the principles of physiology to the children of our schools and to the young people of our colleges, to teach them also the dangers of the use of adulterated foods. They should be taught that to manipulate natural foods in any way to debase them and then continue their sale under their own names is not only a moral, but a dietetic crime; they should be taught that Nature is perhaps

the best judge of the constitution of a food, and that any change in its natural condition, unless incident to its preparation for use, is undesirable and possibly unwholesome and illegitimate; they should be taught to believe that the natural colors of foods are those which should be retained and that no artificial coloring of foods for any purpose should be practiced; they should be taught the danger of using food products mixed with uncertified coal tar colors, which are very apt, with the ordinary methods of manufacture, to contain poisonous and deleterious substances which render them extremely objectionable; and further that the use of vegetable colors to imitate or simulate a natural color can only result in deception, and deception is never ethical, even if at times diplomatic; they should be taught that the misbranding of a food product is a species of adulteration because it conveys to the consumer an idea of the constitution of the food which is not borne out by the chemical analysis; they should also be taught that the laws of many of the States and of the United States require that certain manipulated food products shall bear upon the label a statement of the manipulations to which they have been subjected, the object of this being to notify the consumer of the fact that the thing which is presented to him is not the thing which he would ordinarily expect it to be. The branding on the label of the fact that the food has been adulterated, or that it is misbranded, is not, of course, a drastic remedy for these practices, but it at least brings them into the public mind and lays the foundation of an education which will lead the public in some cases to refuse to use these manipulated articles. If, for instance, a man sells buckwheat flour and mixes it with other flours, he is not allowed under State and National laws to use the term "buckwheat" without limitation, and he is required to state the other constituents. This is one of the least objectionable practices because the flours which are mixed with buckwheat, in so far as we know, are quite as wholesome and nutritious as the buckwheat flour itself, but it notifies the consumer that the article is not buckwheat flour, and it is the same article perhaps which, before the enactment of the food and drugs law, was marked buckwheat flour. If the children of our public schools and the young people in our colleges were taught the art of studying a label, it would do

much to eradicate the misbranding and adulteration which at the present time exist. There are few consumers who, if they had their choice, would not take an unsophisticated article or an unmanipulated one in preference to the adulterated or misbranded product. If they did prefer the misbranded or adulterated article, it would be solely by reason of its price and not by reason of any improvement in its flavor or dietetic quality.

Already steps have been taken in this campaign of education as a remedy for food adulteration. Not only has it been taken up by the newspapers of the country, but also by the weekly and monthly magazines. It has been preached even from the pulpit and very largely from the rostrum. It has been considered by organized bodies such as State and National medical associations, associations of women's clubs, and other clubs formed for civic improvement and progress. Such an opportunity as I have to-day to call attention of this large body of young people to this matter is one of the very means which is most efficient in securing the remedy for the evil. It is indeed a well established evil which can withstand the flood of public opinion. Even the high price of foods had to give way to some extent to public clamor, and no organized and extensive adulteration of food products can long resist the condemnation of intelligent public opinion.

In this great work of information, chemistry must play the leading rôle. It is the chemist who has to determine whether or not a food has been manipulated in any way. He does this because by his researches he finds what are the natural constituents of a food product, what relation they bear to each other, and how impossible it is for man, with all his ingenuity, to artificially disturb these relations without the chemist being able sooner or later to detect what has taken place. If, for instance, it is intended to abstract a part of the butter fat from milk and to add another substance, the chemist will tell you that there is no other fat which Nature has made or man has fabricated which can so simulate butter fat of milk as to escape detection. If it is the case of a salad oil, where the difficulty appears to be insuperable, the same assurance can be given. There are a half-dozen or more oils of a vegetable character which by look and largely by taste simulate so closely olive oil as to deceive any except the professional chemist or a connoisseur, and yet Nature

has so constructed each one of these oils as to give it certain peculiarities which readily enable the chemist to detect it from its fellows. Hence, in the campaign of public education in these matters the teacher must have constant reference to the work of the chemist and must make use continually of those chemical constants which the science of chemistry has established thus peculiarly for each substance.

In the second place: What relation does the science of chemistry bear to the remedy for food adulteration other than by the formation of a public opinion?

In this direction chemistry is supreme. In all countries to-day the evils of food adulteration are recognized as of such importance and persistence as to demand remedial legal treatment. Thus we have seen in the last third of a century in almost all countries of the civilized world, the creation of a legal code defining food adulteration and providing penalties therefor. While these laws vary greatly in detail, in the methods of procedure, to some extent in definitions, and to a great extent in the kinds and magnitude of penalties imposed, they all agree in essential particulars. They all agree that any manipulation of a food product which debases or diminishes its nutritive value, adds a foreign substance, or causes it to be deleterious to health, or deceptive in any way to the consumer, is an adulteration. In all countries it is the chemist to whom appeal is made to determine the nature and extent of the adulteration. It is true that many other sciences are also invoked, but chemistry preserves in all of them its hegemony. Some of the other sciences which are most called upon are bacteriology, botany, physics and microscopy. All of these sciences are utilized as an aid to the chemist, and all are valuable in their applications, and I say nothing to minimize their value, nor in any way unduly magnify the work of the chemist. I only state what is true in every country—that the first person thought of in connection with the execution of a food act is the chemist, and in every country it is the chemist who is given the chief place and who is expected to bear the chief burdens in the enforcement of the law. I to-day must content myself with pointing out only a few of the ways in which the chemist accomplishes this work.

In the first place it is extremely simple to determine by chemical examination whether or not any chemical antiseptic has been added to a food product. No matter how minute it may be, its presence may be detected, and if in considerable quantity, its amount. This is true notwithstanding the fact that in many natural foods traces of these forbidden bodies occur. On certain soils, especially where grapes are grown, some boron compounds enter into the composition of the grape and are found in the ash. In other localities traces of arsenic and copper are found in natural food products, and a few of the organic antiseptics in common use are found in certain products, especially the radicles of benzoic and salicylic acids. Sulphur in some form is found in almost all food products as a natural and essential constituent, especially of protein substances, and this must be carefully distinguished from sulphur compounds added as bleaching agents or as preservatives. The principal thing to be taken into consideration in this matter is that the quantities which Nature places in food products of these forbidden bodies is always extremely minute, entirely insufficient to produce the preservative effects which are required. Hence, the presence in any food product of any preservative, no matter what it is, in quantities which really preserve, shows beyond any question that it has been added to the food and is not present in its natural condition. The simple tests of chemistry, therefore, will at once inform the jury and the court as to the nature of the bodies which are present and also as to their amount. But this is only a small part of the service of chemistry in these matters. It is required in almost all cases in regard to the addition of these substances to foods that there shall be connected therewith the idea of injury to health, and the chemist is called upon to take the principal rôle in the experimental determination of this fact. This action of chemistry is one of its principal relations to biology. It is not usually considered that chemistry is a biological science, and yet there is no science which is so essentially biological in its character as chemistry. Chemistry deals with the very foundations of life, as well as with its modifications, and the processes of nutrition are supremely chemical in character and are controlled by as definite laws as those of multiple proportions. It is in this field of inquiry that the

chemist displays his highest qualifications. I will give some simple problems of this character as illustrations and show how chemistry is applied to them.

First, suppose we consider a substance, "a," which is added to food products and which gives them a certain tint. The chemist first determines what this substance is—whether it is a single chemical body or whether it is a mixture, and if a mixture, whether it is offered in practically the same proportions at all times. Having thus ascertained the nature of the body, he proceeds to determine its effect upon nutrition. To this end the animal life must be utilized, either of man or other animals. This is also coupled with experiments to determine the artificial processes of digestion in the presence of these bodies. Thus we have three different lines of investigation: 1st, artificial digestion, or, as it is called, digestion *in vitro;* 2d, experiments on other animals; and 3d, experiments upon man. These investigations are usually undertaken in the order in which I have named them. It is easier for the chemist to determine what effect, if any, this substance, "a," has upon digestion *in vitro* than to ascertain its effects, especially in small quantities, upon health.

It may have no influence whatever upon the process of digestion either in regard to its character or its extent. In this case a negative conclusion must be formed, that this is a substance which has no influence upon digestion, good or bad. In the third place, digestion may be interfered with either in regard to its proportionate elements or as a mass; in other words, it is either prevented or retarded. In this case the only conclusion which is to be drawn from the experiment is that the substance is of a positively bad character. A digestion *in vitro,* as is well recognized by physiologists, is not a sole test. What effect, for instance, would this body have upon the animal itself? This leads to the second form of investigation in which chemistry takes a more prominent part: Its effect upon animal nutrition. The animals which are employed are kept in as healthy and sanitary environment as possible and are subjected to the test in as nearly as possible similar conditions. Often also a check test is made, that is, the same kind of animals being employed, using the same foods and in the same quantities, but without the substance "a." In the study of animals this way

two kinds of results are obtained. First, the production of symptoms which are observed by a study of the deportment of the animal, the avidity with which it takes its food, the amount of excretion which is obtained, both of urine and of feces, and the chemical and microscopical composition of the excreta. Meanwhile, there has, of course, been determined, either upon these animals or other animals, what the normal course of digestion is, so that the normal amount of food has a certain ascertained relation to the excrement and the general conduct of the animal. The chemist is now called upon to determine whether or not any change is produced in this animal not evidenced under ordinary senses. He studies each individual component of the food as affected by the animal economy. He determines whether or not there is a normal excretion of nitrogen in normal conditions, or whether, as the case may often be, there is an increased or diminished excretion of nitrogen. He does the same for the phosphorus and the sulphur content of the food. He determines the effect of this added body "a" upon the digestion of the carbo-hydrates and fats of the foods. He studies the composition of the feces as compared with their normal composition. He studies the distribution of the sulphur compounds of the urine to see whether or not this normal distribution has been disturbed in any way. He studies the feces and the urine microscopically to see if they contain bodies amorphous or crystallized different from those in the normal urine and normal feces. These studies, of course, must be done with the greatest care and cover a sufficient time to determine certainly that variations are produced. They must also be of such an extensive character as to eliminate the influence of the idiosyncrasy of the animal, which is often of considerable importance. He determines whether the animal is increasing or decreasing in weight during the progress of the experiment. At the end of this investigation he has most valuable data on which to base his conclusions. One of three results may be secured. The influence of "a" may have had a favorable effect upon the metabolism, although it is difficult to determine or to conceive of any favorable effect different from that of natural metabolism. In the second place, the body "a" may have had no effect at all upon the metabolic activities, and the whole

process of nutrition, assimilation and secretion may have gone on exactly as if "a" had not been in existence. In the third place, important variations from normal functional activity may be observed. The quantity of nitrogen excreted may have been increased or diminished, and the same is true of the phosphoric acid and the sulphur. The distribution of the sulphur compounds in the urine may have been changed; the quantity of urea and uric acid may have been increased or diminished. Microscopic, crystalline and amorphous bodies in the urine may have been greatly increased or diminished, etc. In this way we secure data which are capable of intelligent interpretation. If, for instance, the body "a" has caused any material variation from the normal metabolic activity which cannot be shown to be positively helpful, it must be considered by all the tenets of logical exegesis as being distinctly harmful.

There is no other branch of science except chemistry that can compass a work of this kind. Hence there can be no complete study of nutrition and the effects on nutrition of extraneous and foreign bodies except as afforded by the science of chemistry. What is true of "a," a coloring matter, is also true of "b," an antiseptic, and is also true of "c," an apparently harmless filler, and is also true of "d," the withdrawal of any natural constituent of the body, and is also true of "e," an increase in the quantity of any natural constituent, and is also true of "x" or "y," that is, any unknown variation of any kind in a food. If I had time I might illustrate by showing chemical data which have been collected by numerous investigators all over the world to elucidate the points which I have brought out, but these data are not necessary in order that you may understand the supreme importance of chemistry as that branch of science most indispensable and most useful in restricting and abolishing the adulteration of food.

CHAPTER VIII

Food Inspection.*

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Pure water, pure air, and wholesome, unadulterated food may be said to constitute the pillars which form the tripod on which rests the "mens sana in corpore sano." These requirements for human and animal existence were really primarily recognized; but with the development of commerce we find the commencement of food adulteration.†

Although systematic sophistication is an outgrowth of bartering, with its accompanying trickery and deceit, yet it is not possible in primitive states of society; and even in the semi-pastoral state commercial frauds of this nature are unknown or undeveloped. However, the adulteration of alimentary substances was practiced in the civilized countries at a very remote date. Pliny refers to the adulteration of bread with a white earth, and in Athens and Rome wine was much tampered with; in fact, certain residents of Athens, among them the ingenious Canthare, so excelled in imparting the flavors of age and maturity to new wines that a special inspector was appointed to detect and stop these practices. This early record of inspection is indicative of the attention which the ancient civilized peoples gave to sophistication, a practice which did not, however, be-

*Mr. Bayard C. Fuller, Chief Food Inspector of New York City, in a lecture described the procedure in the Department of Health. We are indebted to him for the selected illustrations which accompany this chapter. Sufficient is presented to show the necessity of constant supervision, the need of education, especially among the poorer classes, and the value of able, conscientious, and sympathetic enforcement of the law.

†In general, a food may be considered to be adulterated if anything has been mixed or packed with it to reduce or lower its quality or strength; or if anything inferior has been substituted wholly or in part therefor; or if any valuable constituent has been abstracted wholly or in part from it; or if it consists wholly or in part of a diseased, decomposed, or putrid animal or vegetable substance; or if by coloring, coating, staining, powdering, or otherwise, the inferiority in character is concealed; or if it contains any added poisonous ingredient (external preservatives, and unwholesome preservatives and colors).

The object of food inspection is not only to prevent the manufacture, sale, and transportation of adulterated foods, but also to enforce proper branding and to prevent the sale of naturally deleterious foods.

come frequently corrupt until the Middle Ages. Then it was, from the eleventh century onwards, an epoch of general low morality, that the bakers, brewers and vintners were accused of many nefarious practices. Bread in particular received much attention from the medieval sophisticator, and in England, as early as the reign of King John, the sale of the commodity was controlled by the "Assize of Bread," which included penalties for falsification. In France, in 1382, it was found necessary to promulgate ordinances specifying the proper methods of bread-making, while in Germany, during the fifteenth century, the bread adulterator was punished rather severely. In Nuremberg almost all foods were regularly inspected, and in all the cities of Germany there were elaborate regulations with regard to bread, wine and drugs.

The early attempts to control and punish adulteration, particularly of wines and bread, are of importance in that they were the precursors of the protective legal measures which exist in more modern times. In 1802, the "Conseil de Salubrite" was established in Paris; it took cognizance of adulteration, and the work accomplished was so useful that most of the provinces followed the example of the capital. It is to these numerous boards of health that the French are at present mainly indebted for what immunity from adulteration they enjoy. In 1874, the Society of Public Analysts was organized in England. This society formulated a legal definition of adulteration and issued the standards of purity to which articles of general consumption should conform; it was supported in its work by the enactment, in 1875, of the Sale of Food and Drugs Act.

Battershall has attributed the retardation of early systematic action in the matter of adulteration in the United States to the "American characteristic of controlling their own personal affairs and the resulting disinclination to resort to anything savoring of parental governmental interference." True, sporadic efforts to secure legislation were occasionally made and laws of a specific nature were passed, but all such legislative restrictions became subsequently dead letters; and the enactment of more comprehensive laws allowed loopholes through which the offender could escape. The culmination of agitation against food adulteration, a practice which was becoming unfortunately gen-

eral, was in 1877, when several of the State Boards of Health —notably those of New York, Massachusetts, Michigan and New Jersey—instigated the formulation of laws against adulteration, and commissioned chemists to collect and examine samples of foods; but it was not until 1903 that active measures were taken by the Government to establish high standards of purity for food products and to determine what are regarded as adulterations therein. Through the collaboration of representatives of the Official Agricultural Chemists of the United States and of the Interstate Food Commission with the Agricultural Department, standards of purity for food products were established; and in 1906 the "Food and Drugs Act, June 30, 1906," was passed. This Act, one of a protective and comprehensive nature, is at present in force, and it has been most effective in preventing the manufacture, sale and transportation of misbranded, poisonous and deleterious foods, drugs and liquors.

The determination as to whether a food is genuine or adulterated within the meaning of the law, and, if adulterated, how and to what extent, rests with the analysts employed by the Government, States and various cities.* Such analysts pass

*The following list includes the foods most exposed to falsification, together with the adulterants used:—

Article.	*Common Adulterants.*
Bread and flour.	Other meals; alum; ergot.
Butter.	Water; coloring matters (carrotin, etc.); oleomargarine; other fats; preservatives (boric and salicylic acids, etc.).
Canned foods.	Metallic poisons; products of decomposition; "soaked goods"; preservatives.
Cheese.	Lard; oleomargarine; cotton-seed oil; manufacture from skimmed milk; metallic salts (in the rind).
Cocoa and Chocolate.	Cocoa shells; sugar; starch; flour; alkali.
Coffee.	Chicory; starch; peas; rye; corn; date stones; coloring matters (yellow ochre, turmeric, etc.); glazing (egg, sugar, gum).
Confectionery.	Dextrin; glucose; starch; artificial essences; poisonous pigments; terra alba; talc; plaster of Paris; paraffin.
Honey.	Glucose sirup; cane sugar; gelatin.
Lard.	"Compound lard"; stearin; cotton-seed, corn, cocoanut, peanut and sesame oils; water.

Continued on following page.

judgment on articles of food purchased or seized on the open market by collectors of samples, and in general the analyst is not aware of the data of collection nor the name of the person from whom the purchase was made.

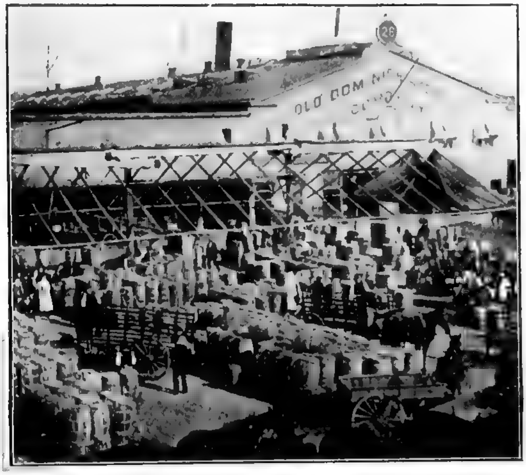

FIG. 75.—SCENE AT THE PIER OF THE OLD DOMINION STEAMSHIP COMPANY, NEW YORK CITY, WHERE LARGE SHIPMENTS OF FRUITS AND VEGETABLES ARE RECEIVED.

Milk.	Water; removal of cream; coloring matters (annatto, azo-dyes, etc.); preservatives (formaldehyde, etc.).
Mustard.	Flour; turmeric; cayenne; mustard hulls; terra alba; starch.
Olive Oil.	Cotton-seed, corn, peanut, cocoanut, and other fatty oils.
Pepper.	Various ground meals; pepper shells; ground olive stones; buckwheat middlings.
Pickles.	Salts of copper; alum; sulphuric acid.
Spices.	Pepper-dust; starch; rice; flour; ground fruit stones; charcoal; sawdust.
Sugar.	Dextrin; glucose; organic non-sugars.
Tea.	Exhausted tea leaves; foreign leaves (leaves of the willow, poplar, elder, birch, elm, and rose); stems and fragments, and "tea dust" ("lie tea"); added astringents (catechu); and substances used to "face" the dried leaves (indigo, Prussian blue, gypsum, soapstone, and plumbago).
Vinegar.	Water; sulphuric acid; spices; caramel; wood vinegar; metallic impurities.

This list is illustrative of the varied nature and great importance of the food analyst's duties.

The investigation of the adulteration, false labeling, and false branding of foods is conducted by the Government in the Division of Foods of the Bureau of Chemistry, United States Department of Agriculture, and food and drug inspection laboratories have been established in Boston, Buffalo, Chicago, Cincinnati, Denver, Detroit, Galveston, Honolulu, Kansas City, Nashville, New Orleans, New York, Omaha, Philadelphia, Pittsburg, Portland, St. Louis, St. Paul, San Francisco, Savannah and Seattle. A rigorous system of inspection is conducted, and for the information of the public the principal food inspection decisions are published. The scope and nature of the regulations governing the meat inspection of the Agricultural Department are of particular interest. According to these regulations, all slaughtering, packing, meat-canning, salting, rendering or similar establishments whose meats or meat food products, in whole or in part, enter into interstate or foreign commerce shall have inspection unless exempted. An ante-mortem examination and inspection is made of all cattle, sheep, swine and goats about to be slaughtered; at the time of slaughter, a careful inspection is made, and only carcasses and parts found to be sound, healthful, wholesome and fit for human food are passed; and diseased carcasses and parts are suitably disposed of. Carcasses affected with tuberculosis, and those showing lesions of anthrax, blackleg, pyemia and septicemia, are no longer converted into meat products to feed an unsuspecting public, and "embalmed beef" is a food of the past.

The food inspection work conducted at the sixty-two Agricultural Experiment Stations located throughout the United States has been of an important nature. In 1902, however, only eight States (Connecticut, Illinois, Indiana, Kentucky, Louisiana, Maryland, Massachusetts and Michigan) and the District of Columbia had officers charged with the enforcement of their food laws, although Delaware maintained inspectors of breadstuffs, and California, Colorado and Iowa had dairy bureaus. Later, particularly after the passage of the National Food and Drugs Act of 1906, considerable attention has been paid to the examination of food products collected by the stations, and contributed by health officers, consumers and dealers. In Connecticut, for example, 1,594 samples were examined at the

State station in 1907-8, and excellent work is being carried out all over the country under the provisions of the various State pure food laws. The association of State and National Dairy and Food Departments directly co-operates with the Association of Official Agricultural Chemists.

As an example of what has been accomplished and is being done by city food inspection, the metropolis of the country may be most appropriately taken. Here food inspection in all its

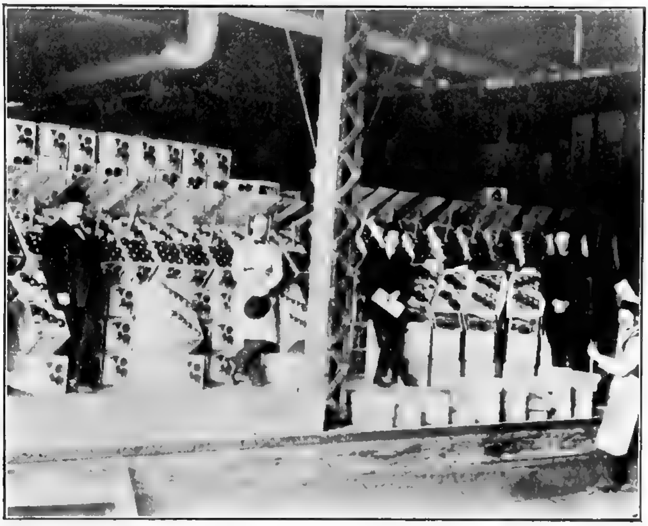

FIG. 76.—A MARKET SCENE, SHOWING FRUIT EXHIBITED FOR WHOLESALE, NEW YORK.

varied forms is of the greatest significance, for every food product known to mankind finds its way to New York, and what is not consumed by the inhabitants is shipped to various parts of the country. The Division of Inspections of the Department of Health of the City of New York contains a highly important subdivision, that of the Inspection of Foods. Aside from the examination of the physical condition of food products—that is, the inspection of fruit and vegetables at the wholesale markets, and of fish and meat—the department maintains a well-equipped chemical laboratory, where nearly 4,000 samples of food are analyzed annually.

The Supervising Inspector of Foods of New York City has charge of the inspection of fruits, vegetables, and fish in the

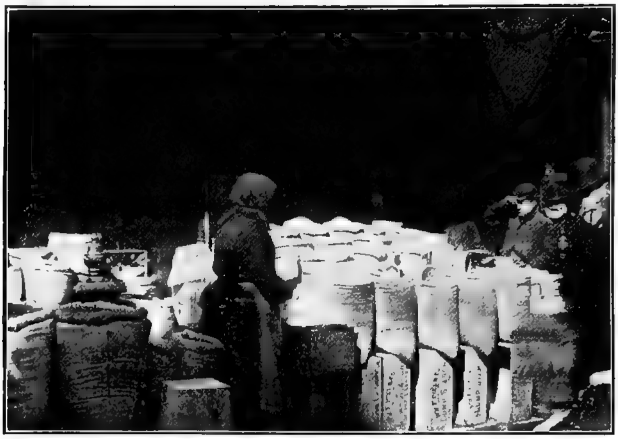

FIG. 77.—AN INSTANCE OF FOOD EXPOSURE—NOT BAD FOR THE KIND OF FOOD, NEW YORK.

Borough of Manhattan and of imported fruit which is landed in the Borough of Brooklyn. The inspectors under his direc-

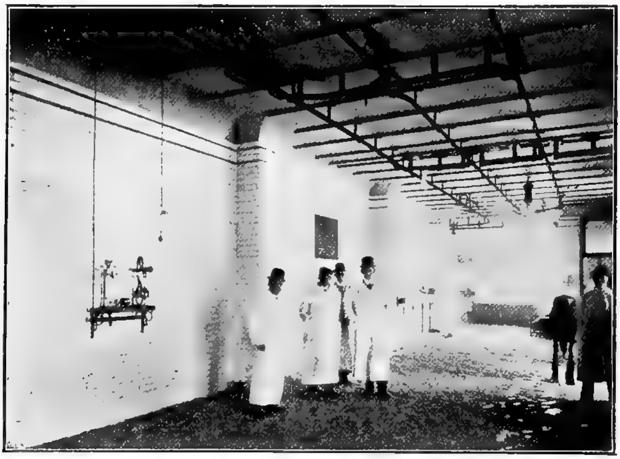

FIG. 78.—INTERIOR OF A MODERN ABATTOIR IN NEW YORK CITY.

tion carefully examine food products of the above nature, and in cases wherein a superficial examination will determine the

quality, the food which is unfit for consumption is immediately condemned, disinfected, and removed to the city's dump. Care is especially taken to see that the final disposition is not that of consumption. At stated periods the inspectors are changed so that by a rotary system every inspector becomes familiar with every district in the city. From the nature of the work, it is also necessary to assign inspectors to a special kind of work; therefore, there is one man who is kept at the wholesale market along the river front for eight months in the year, and this supervision is maintained during the night time. There are

FIG. 79.—CARELESS EXPOSURE OF POULTRY—FORMERLY NOT AN UNUSUAL SIGHT, BUT NOW RARELY SEEN IN NEW YORK.

also others who are detailed to examine the foods offered for sale in the large stores, by wholesale grocers, importers, supply houses, and brokers; and an inspector is assigned to take charge of the railroad yards and the river front. The Borough of Brooklyn has one inspector; he examines imported foodstuffs and his territory is limited to the shore front.

The agitation which resulted throughout the country upon the passage of the Pure Food and Drugs Act in 1906 did not increase the activity of the Department in food inspection, since section 68 of the Sanitary Code has been enforced for a number of years. It did serve, however, to assist in bringing into close relationship all of the food manufacturers with the Health

authorities. When the agitation in relation to the meat packing industry occurred, all places in Manhattan where sausages were sold and manufactured were inspected, and as a result the practice of using borates and coal tar dyes is no longer general. At present, all slaughter houses, stockyards, and shops are visited regularly, and the unnecessary and dangerous practice of using sulphurous acid in chopped meat has been practically eliminated. The meat which is destined for use in hospitals is always examined with particular care as to its general condition; and the disposal of the blood and offal from the "Kosher" meat slaugh-

FIG. 80.—A TYPICAL SCENE IN THE EAST SIDE, NEW YORK CITY. Exposure of dried fruits in pushcarts. This is against the law and is gradually being eliminated.

ter houses requires constant supervision. Meat which is condemned is immediately destroyed in the tanks which are used for the destruction of the offal from the slaughter house.

All of the ice houses and cold storage buildings connected with the fish markets of the city are inspected regularly, and in the summer months precautions are taken that only the best fish go into the freezer. For a number of years the Department experienced great difficulty in attempting to remedy the evils of the Fulton Fish Market. Finally, however, by constant vigilance, care, threats and diplomacy, practically a normal condition now prevails, and there have been few complaints from citizens, who formerly had wearing apparel ruined by coming in contact with fish and fish slime.

In 1905, the Department examined all of the retail confectionery stores and cellars where candy is manufactured. It was found that, in many instances, the utensils and conditions were decidedly unsanitary, and people lived in close proximity to their work. About 3,500 places of this character were inspected, as a result of which nearly 400 notices or orders were issued. Similar attention was given to the bake shops, maccaroni manufactories, and retail grocery stores; the practice of drying maccaroni on the sidewalks was especially discouraged. During 1908, in all stores where ice cream is manufactured

FIG. 81.—EXPOSURE OF CANDY.
Glass covers for food pushcarts were required by the Department of Health, but it is not easy to see that the street venders keep the covers down.

utensils used in the manufacture were carefully examined, and, when necessary, orders were given either to purchase new or repair the old utensils. Among the substances used in flavoring extracts, the lemon juice substitutes have been driven out of the market.

It is the custom of the Department to immediately inspect merchandise to be used for foodstuffs which may be damaged by fires, and for this purpose the Department receives reports from the Phoenix Insurance Company. The New York Mercantile Exchange has elected a representative of the Department to floor privileges, and the latter may now come in direct touch with the dairy interests. In fact, the Department receives

encouragement from all sources, but the Court of Special Sessions has been most effective in furthering the interests of public health, since recently the judges of this court have increased the fines imposed for the adulteration of foods and have given warnings that a second offènse will meet with imprisonment.

In conclusion, the object of bromatology and food inspection is to improve the conditions of the supply of foodstuffs and not to destroy industry. An example of such a purpose is to be found in the work of the Health Department of New York City, which is illustrated herewith.

CHAPTER IX

Drugs and Their Adulteration.

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The term "Drug," as interpreted by our Food and Drug Law, means any medicinal agent, be it of mineral, vegetable or animal origin, or a coal-tar product. By adulteration in the narrow sense, we understand the mixing of a drug with one of lower grade or inert matter, for the purpose of enhancing profit or meeting competition.

Taken in the general sense of the term that the purchaser receives something different from that which he should anticipate, the subject becomes a very broad one, and this is the standpoint of the United States Pharmacopœia, our National Drug Codex.*

Limited space admits a consideration of this important subject only in general outline, with the citation of typical examples under the various heads. Understand, however, that adulteration is not as general as might be assumed, for during recent years much progress has been made in combating this practice legally as well as through educational channels.

Intentional Adulteration.—This represents the very worst phase of the evil since the motives are purely for gain, while deception and fraud are perpetrated upon the sick and injured, a crime of the worst type.

Intentional adulteration of medicinal chemicals, excepting

*In response to a general demand, emanating from the College of Pharmacy of the City of New York, seconded by medical and pharmaceutical institutions, our first law regulating the importation of drugs and chemicals was enacted in June, 1848. Up to this time, our country was the veritable dumping ground of Europe for adulterated medicinals. It was shown that many of the more important chemicals used in medicine were entirely substituted by inert ones. The necessity of this law was demonstrated by the fact that during the first nine months following the enactment of this act of Congress 90,000 pounds of drugs and chemicals imported were rejected—very significant figures considering the lax standards of those early days. With the tremendous progress made in the arts and sciences, during the 60 years intervening, drug inspection is today exacting and accurate, so we are assured of high-grade goods, if the intent of the law is conscientiously executed.

that of the coal-tar products, is quite rare; in fact, such chemicals as are sold in original containers by our manufacturers are never adulterated. Such cases as do occur among bulk goods, may be traced to curb-brokers or other irresponsible parties. Occasionally we hear of the following: arsenious acid mixed with gypsum or china clay; litharge (lead oxide) with brick dust; light calcium carbonate mixed with magnesia carbonate to increase its lightness and bulk; cream of tartar with alum or calcium phosphate; borax mixed with or entirely substituted by sodium bicarbonate; precipitated sulphur containing as much as 75 per cent. of calcium sulphate.

Criminal is the practice carried out by traveling vendors, also by firms of many aliases, located in Canada and Switzerland, who offer certain well-known medicinal coal-tar products at lower rates than sold by responsible parties. These remedies are put up in imitation packages or are sold as being identical in composition with the genuine. Thus, imitation packages of sulphonal, trional and phenacetin are filled with acetanilid; veronal substituted by malonal, a cheaper but more dangerous succedaneum; thymol iodide, an antiseptic, mixed with unclean inert matter or so carelessly made that when introduced into a wound causes either infection or iodism. Thymol, an aromatic antiseptic, is occasionally admixed with paraffin. Vanillin and coumarin are frequently mixed with acetanilid. Creosote, the value of which depends on the guaiacol content, appears frequently practically minus the latter.

Among the essential oils, adulteration is extensively practiced, either in the addition of some inferior grade of the oil, some other similar oil, or turpentine, or through the withdrawal of a part or all of the most valuable constituent. Such deceptions are carried out with skill and are more or less difficult to detect, owing to the complex character of most of the essential oils, which consist of mixtures of one or more odor or flavor carrying constituents and an inert vehicle, a terpene or a mixture of terpenes. Some essential oils have always been adulterated so that the public would fail to recognize the pure article if supplied, as, for example, otto of rose. As examples of oils from which the flavor-carrying principles are frequently removed, we may cite; lemon (citral), anise (anethol), thyme (thymol),

peppermint (menthol), clove (eugenol), cinnamon (cinnamic aldehyde), sandalwood oil (santalol), etc. Oils adulterated with rectified turpentine, alcohol, kerosene or low grade oils, are cinnamon (rosin, petroleum), eucalyptus (eucalyptus oil with much phellandrene), juniper berries (turpentine, juniper wood oil), lavender flowers (from plants), copaiba balsam (gurjun balsam), anethol (low grade fennel oil), citronella (kerosene, alcohol, terpenes), bergamot (turpentine, colored lemon oil), lavender flowers (turpentine, rosemary oil, oil from the plants), otto of rose (geranium, geraniol), etc.

Until the enactment of the Food and Drugs Act, pure powdered spices were rather the exception than the rule. The trash sold to the public was amazing. Such admixtures as gypsum, calcium carbonate, brick dust, clay, flour bran, screenings, ground cocoanut shells, clove stems, pepper shells, powdered olive seeds, exhausted spices and many others, were very common. With standards now established by the government, it is only a question of enforcement of the law.

Adulteration and substitution have been practiced among botanic drugs from the earliest times and even to-day more than in any other line of drugs. It is only recently that any attempt at a systematic inspection by experts has been made by our government on drugs entering into our ports. Those indigenous in our country pass directly into commerce. Adulteration in this line is not as readily controlled as in others, because it requires not only careful training and long experience to be able to distinguish true from false drugs, but also means of chemical assay are totally lacking among many of the more common ones.

Adulteration of drug powders is very common, not only through the addition of foreign inert matter, but also through the employment of worm-eaten, inert, exhausted drugs or other parts of the same plant. The detection of such admixtures requires special training and at times is attended with difficulty. Such adulterated drugs get into the market through the ignorance of the buyer, the carelessness of the collector and cupidity of some dealers. As instances we may cite the following:

Alstonia constricta (Australian fever bark) is substituted by or admixed with the *A. scholaris,* unlike the former, as well as

by a powdered mixture of wild cherry bark, goa powder and cinchona; asafœtida is largely admixed with sand. Opium is mixed with stones, clay, gypsum, litharge, resinous and mucilaginous substances. *Hydrastis canadensis* (golden seal) is mixed with any rhizome that possesses the same yellow color. Jaborandi leaf, an active drug, is not only adulterated with leaves from other plants which resemble it, but also the practice of substituting one variety for another has become more common than the supplying of the genuine leaf. Lobelia seeds are frequently altogether substituted by the "Mullein Seed"; larkspur seed for stavesacre; *apocynum* (Canadian hemp) has been so frequently substituted by roots of several other species that the genuine drug has fallen into discredit. According to Rusby,* three totally different plants are called "Pink Root" in our southern states, hence the official drug (*spigelia marilandica*) is substituted, or adulterated, to the extent of 75 per cent. He also states that less than one-half of the male fern sold is really genuine, owing to the careless substitution of other species; also a so-called "French cultivated stramonium" of "Superior Quality," was found to be in no way related to stramonium and devoid of mydriatic properties.

Quoting further from Rusby, "no drug is more certain or prompt in its action or used more urgently in vital cases, than strophantus (a heart stimulant), yet more than 75 per cent. of that used is spurious; one variety is nearly inert, and I could cite a number of fatal cases resulting from failure to get its action."

Beeswax is still attractive to the sophisticator since we meet such additions as starch, sand, and corn-meal. More difficult of detection is the substitution of mixtures of beeswax with stearic acid, paraffin or carnauba wax, or a mixture of the latter three without beeswax.

Therapeutic Substitution.—This occurs quite frequently in that drugs of similar medicinal properties obtained from other members of the same family are sold for one another. Usually the substitute is of inferior medicinal quality. Those who carry

Merck's Report, 1905, 202.

on this practice are under the impression that the substitution of a similar drug makes no real difference, and in some instances, when the drug is of harmless nature, as is the case among the sarsaparillas, there is no real difference in result. Thus, other varieties and allied substances are frequently sold as a true kino; Curacao, Cape and Natal aloes for the Socotrina; roots of many plants resembling ipecac; one kind of cinchona bark for another; one variety of cocoa leaf for another. The substitution of soaps from animal fats for powdered castile soap is common, as is the substitution of synthetic methyl salicylate for oil of wintergreen, cinnamic aldehyde for oil of cinnamon, and benzaldehyde for oil of bitter almonds.

Another reprehensible practice is the substitution of chemicals of unknown manufacturers for copyrighted ones, as acetyl salicylate for aspirin; diacetyl morphin for heroin; acetylamidosalol for salophen; various sulphonated hydrocarbons or shale oil for ichthyol; diethylbarbituric acid for veronal; bismuth tribromphenol for xeroform; dimethylamido-antipyrin for pyramidon; nucleinate of silver for argyrol and nargol; proteinate of silver for protargol; quinin ethyl carbonate for euquinin, and so on.

While some of these substitutions are identical with the copyright article, yet what protection has the patentee for his products, when sharks are permitted to flood the market with what is in many cases an inferior article, after the former has been to the expense in developing and exploiting his invention?

Deteriorated Drugs.—Deterioration of drugs and chemicals may be brought about through careless storage, and, while many are indifferent to such conditions, others are totally ruined. Thus, simple exposure to the light, although contained in well stoppered bottles, will cause decomposition to take place in mercurous iodide, calcium sulphide, iodides of ammonium and zinc, morphine acetate, silver salts, chlorine water, chloroform, etc. Storage and occasional opening of the containers are sufficient to bring about deterioration of ammonium carbonate, sulphites, tablets of nitroglycerin, hypochlorites, hydrocyanic acid,

hydrogen peroxide, oil of bitter almonds, ethyl and amyl nitrites, etc.*

Natural deterioration among the more sensitive chemicals is unavoidable and is recognized by the United States Pharmacopœia under restrictions in some instances. Exposure to air causes a rapid deterioration of such drugs as contain volatile oils, like cinnamon, clove buds, lavender flowers, peppermint, etc. The growth of fungi, which readily takes place on damp drugs, especially leaves, causes rapid deterioration with decomposition of their alkaloids, as with the cactus grandiflora, jaborandi, stramonium, cocoa and digitalis leaves.

Insects readily attack such drugs as poke root, jalap, rhubarb, ergot, taraxacum, aconite, gentian, ginger, burrowing through them until they are transformed into an unsightly porous mass; powdered cayenne pepper and paprica are breeding grounds for a kind of moth which spins webs through the mass. In this list may be included drugs collected at the wrong time of the year, as spring collected podophyllum root, which is worthless; leaves of hyoscyamus and digitalis of the first, instead of the second, year's growth, which are of but little value.

Accidental Adulteration.—This exists chiefly among botanic drugs and spices, since their collection is mainly in the hands of ignorant or semi-civilized people. We find stems, twigs and foreign leaves among leaves, foreign roots and dirt among rhizomes and roots, stems and inert berries among good ones. For example, Kebler† quotes instances of chimaphila leaves mixed with 25 per cent. of stems; jaborandi leaves with 16 per cent. of twigs and stems; cocoa leaves with 18 per cent. of foreign material; cubebs with 15 per cent. of stems and 11 per cent. of worthless berries yielding 6.4 per cent. of oil instead of 12 per cent.‡

*There is no question as to the accuracy of these statements. The important point of the matter depends upon, first, the ability of the dispenser to recognize such deterioration; and second, the willingness of the druggist to destroy and not dispose of such articles when a pure article is asked for by the purchaser or prescribed by the physician. The former reflects upon the schools of pharmacy, which are not now to be found fault with, and the latter exhibits a condition of cupidity against which all forms of educational activity should and do enveigh, and which should be freely made known by those competent not only to the community but the official boards which grant licenses. No words are sufficiently strong to condemn such ignorance or, worse still, contemptible practices.—C. B.

†Bureau of Chemistry, Department of Agriculture, No. 1.

‡The lecturer exhibited a number of such, as well as other, illustrations of adulteration. Unfortunately these cannot be shown in printed pages—but "he who runs may read."—C. B.

All crude drugs, good, bad and indifferent, are bought up by merchants, who have only a general knowledge in this line. These then pass through the hands of brokers to the wholesale drug dealers, drug millers and manufacturers of pharmaceutic galenicals. The two former classes are generally without anyone qualified as drug experts, while the latter class is compelled to exercise more care, since many of their products are subject to assay. Foreign drugs that pass through the New York port of entry are now subject to official inspection, resulting naturally in a great improvement in their quality.*

Convential Mixtures.—In order that a drug may be rendered more attractive in appearance, various practices have been in vogue since the earliest times. The public, as well as buyers, have become so accustomed to this unnecessary treatment that the drug in its original state would scarcely find a market.

The cochineal insect is silver grained by shaking with talcum; the black grained insect would not be recognized by the public. Ginger rhizomes are bleached and limed to make them more presentable. Nutmegs were originally dipped in lime water by the Dutch, either to destroy their vitality to prevent transplanting, or, more probably, to protect them against the attacks of insects.

The United States Pharmacopœia has established standards of purity for the majority of the more important chemicals, and standards for alkaloidal activity among the potent drugs. There are, however, many drugs whose activity does not reside in an alkaloid, glucoside or resin, hence the establishment of standards for these is a difficult question. It is only a matter of time until standards of identity for these will be devised, when an accurate control may be exercised. It remains at present for us to secure a more rigid enforcement of the present standards of the Pharmacopœia, and to secure in the next revision a more rational standardization than now appears.

*It is to be hoped that local boards may acquire the power, and exercise it, of scrupulous inspection of domestic drugs. A few cases of determined guilt with severe penalty will practically eradicate the evil.—C. B.

CHAPTER X

DRUGS—METHODS FOR DETECTING ADULTERATIONS.

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Having considered the various forms of adulteration of drugs and their substitutes, attention may be directed to means for determining such. It is quite out of the question to repeat here the details which are followed, more or less, in making an analysis of the common, or uncommon, inorganic chemicals. Those are matters for an expert. This is equally true, to use an Irishism, of the more difficult kind of analysis, which has to do with plants and animals with their multitudinous variety of substances. These are hard to isolate, and when isolated yield sullenly to methods for their characterization and quantitative determination. Only the outlines may be indicated, so that the student, or he who is really interested, may follow the literature, thus gaining an insight into the difficulties while acquiring a degree of knowledge, which sinks before his recognition of the need of wide study, and may gain an acquaintance with the intricacies which attend passing an opinion upon organic drugs.

CRUDE DRUGS.

To distinguish the true from the false, or adulterated, drug requires an accurate knowledge of the external and internal morphology and chemical constituents of drugs. This is embraced under the study of Pharmacognosy.

The physical and microscopical characteristics of every root, rhizome, leaf, seed, bark or twig used in medicine, has been so thoroughly studied that the experienced pharmacognosist rarely errs in his diagnosis.*

The microscopical study of the morphology of plant organs has reached a high stage of development, enabling the operator

*It will be impossible here to enter into the physical diagnosis of drugs. The literature bearing on this subject is referred to at the end of the chapter.

to not only identify the various crude drugs through sections, but also in the powdered form, where the general structure has been destroyed.

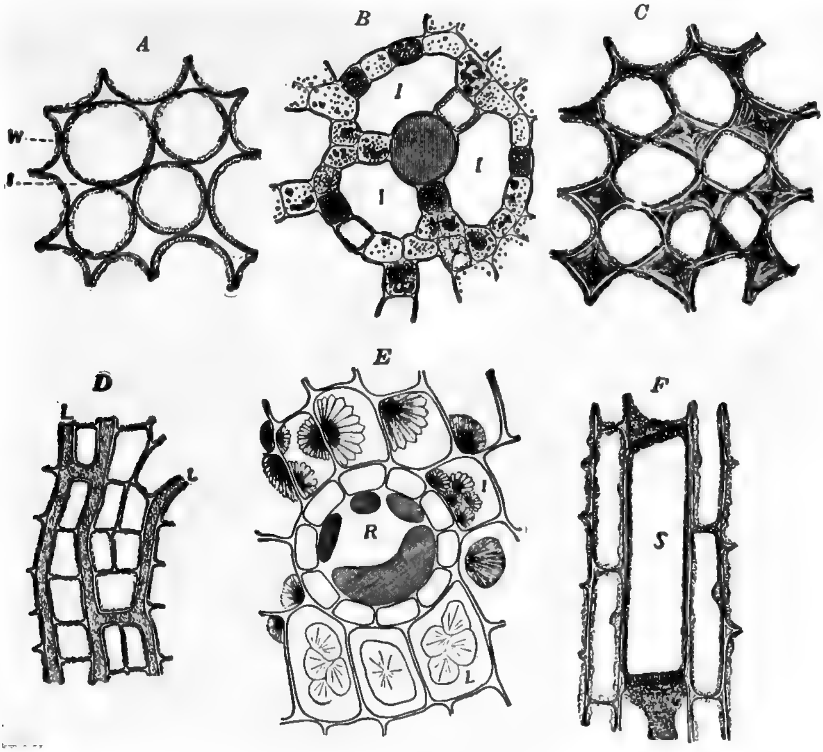

FIG. 82.—FORMS OF CELLS.

A.—Transverse section of the pith of *Tradescantia virginica:* I, intercellular space; W, cell wall. B.—Transverse section of calamus rhizome showing a large oil-secretion cell, smaller cells containing starch, and large intercellular spaces (1). C.—Transverse section of the stem of *Phytolacca decandra* showing collenchymatous cells beneath the epidermis. D.—Longitudinal section of taraxacum root showing branched laticiferous tissue (L). E.—Transverse section of pyrethrum root: R, oil-secretion reservoir with oil globules; I, cells with sphere-crystals of inulin, such as separate in alcoholic material; L, cells containing masses of inulin, as found in dried material. F.—Longitudinal section of stem of *Cucurbita Pepo:* S, sieve-cell with protoplasm-like contents, and transverse walls (sieve plates) showing simple pores.

(Permission of Prof. Henry Kraemer.)

In order that the uninitiated may gain a general idea of this subject, a review of some of the chief histologic elements which form points of identity or distinction under the microscope, is given.

Tissues.—Sections of various parts of plants show that their general structure is made up of a great variety of cells, variously grouped and shaped. Such cells of similar forms and functions are classified as: (1) *Parenchyma,* thin walled cells of cellulose, isodiametric or elongated, colored blue by chlorzinc iodine and soluble in Schweitzer's reagent. (2) *Collenchyma* cells are long, thickened at the angles, walls composed of cellu-

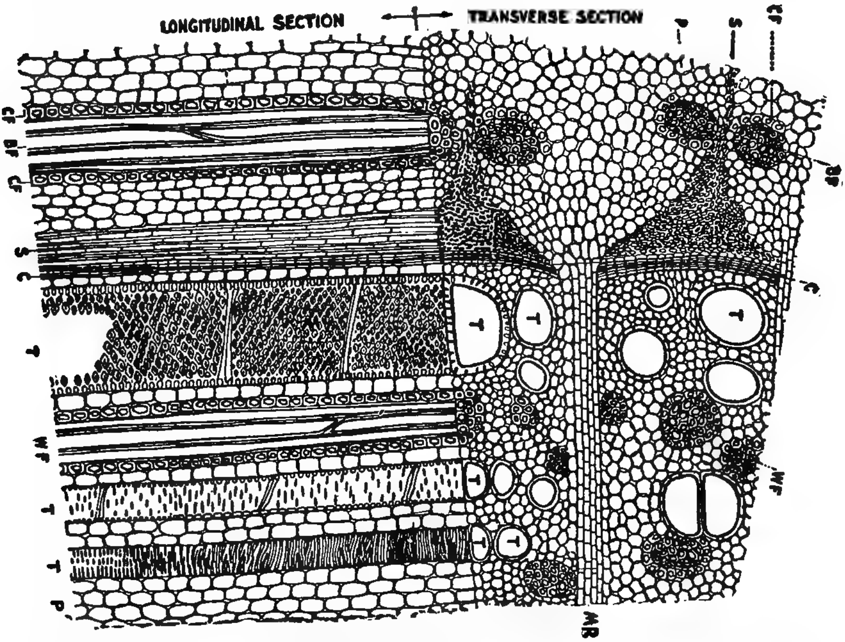

FIG. 83.—LONGITUDINAL-TRANSVERSE SECTION OF LICORICE RHIZOME INCLUDING THE CAMBIUM.

P, parenchyma; T, tracheæ or ducts; WF, wood fibers; C, cambium; S, sieve; CF, crystal fibers; BF, bast fibers; MR, medullary ray.

(Permission of Prof. Henry Kraemer.)

lose, and are found beneath the epidermis of herbaceous stems, petioles and angles of all stems. (3) *Sclerenchyma* cells are those with more or less thickened walls composed of ligno cellulose and permeated by simple or branching pores (Kraemer). (4) *Conducting parenchyma* assist the diffusion of sap from one part of the plant to the other. The sclerenchyma cells may either have their walls thickened by inorganic matter (stone cells) or may be elongated, and are known as bast or wood

fibers. When the conducting elements of plants are grouped into bundles made up of bast fibers, sieve tubes, ducts, etc., we call them fibrovascular bundles.

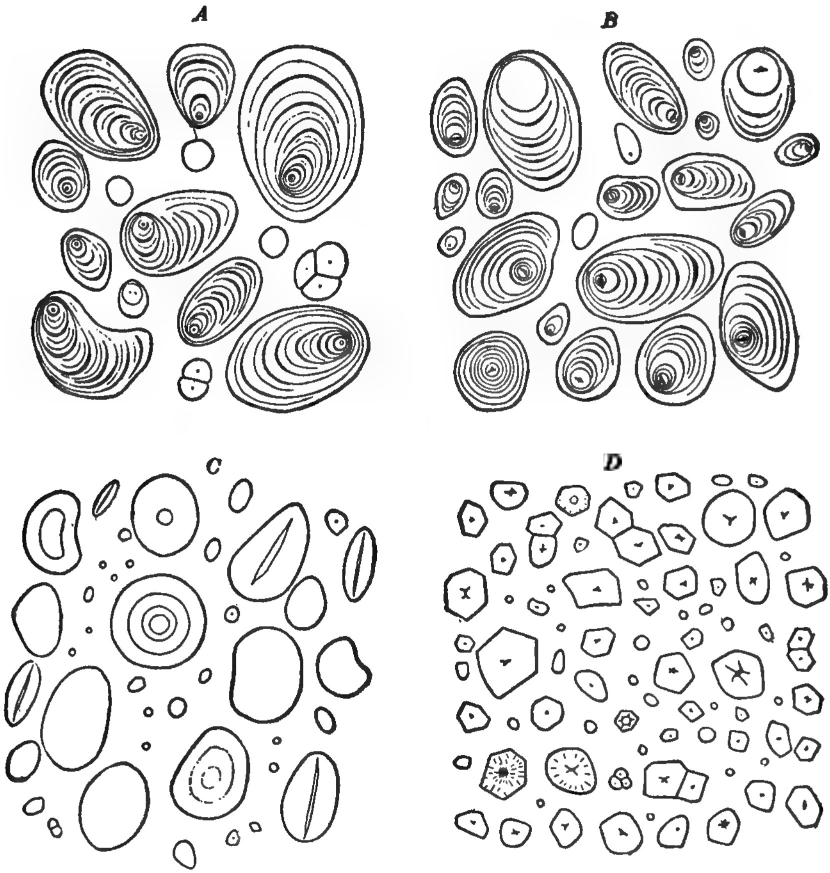

FIG. 84

A, potato starch grains showing the excentral and circular point of origin of growth and lamellæ; B, maranta starch grains showing fissured point of origin of growth, and distinct lamellæ; C, wheat starch grains showing indistinct point of origin of growth, and lamellæ; D, corn starch grains, which are more or less polygonal in outline and have a 3- to 5-angled point of origin of growth.

(Permission of Prof. Henry Kraemer.)

If the transverse walls of certain superimposed cells be removed, elongated cells or tubes, called ducts (tracheæ), are formed; if there be thickenings in form of horizontal rings, we

call them annular ducts; if the thickenings are spiral formed or reticulate or step-like, they are known as spiral, reticulated or

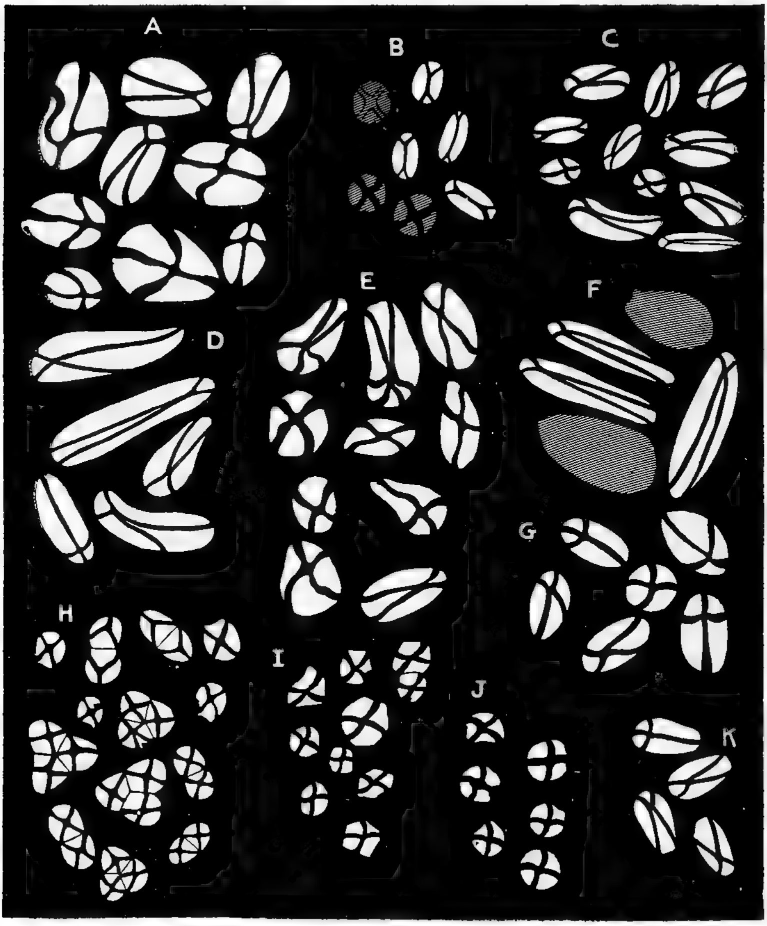

FIG. 85.
Larger grains of various starches as viewed through the micropolariscope when mounted in oil: A, potato (70-80 μ); B, wheat (30-40 μ); C, ginger (30-50 μ); D, galangal (45-55 μ); E, calumba (40-50 μ); F, zedoary (50-75 μ); G, maranta (35-50 μ); H, colchicum (10-20 μ); I, corn (20-25 μ); J, cassava (20-35 μ); K, orris root (30-35 μ).
(Permission of Prof. Henry Kraemer.)

scalariform ducts. Intermediate between the ducts and wood fibers possessing bordered pores are the tracheids. According to their functions and composition, the protecting or outer plant

cells are classed as epidermal cells or those which form the outermost layer of the plant; they lessen the rate of evaporation and protect the inner tissues. The cork cells have thickened walls consisting of a substance called suberin; their function is to replace the more tender epidermal cells as a protective covering.

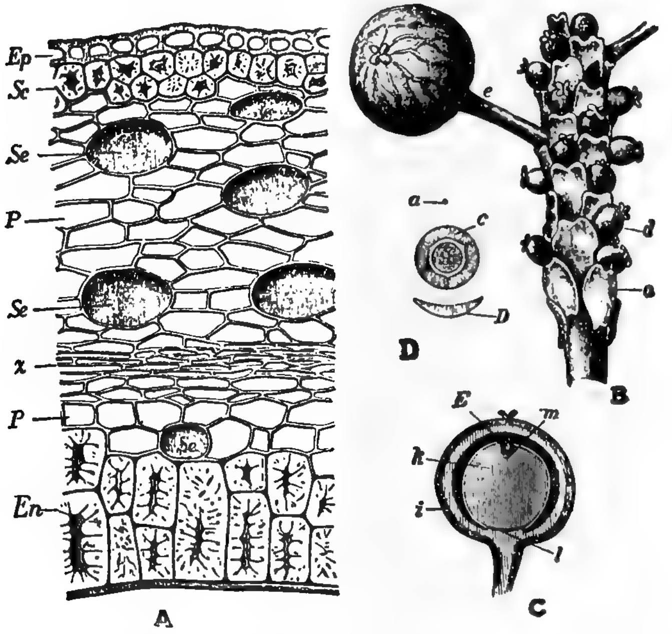

FIG. 86.—CUBEBS.

A, transverse section of the pericarp showing epidermis (Ep), stone cells (Sc), oil cells (Se), parenchyma (P), collapsed parenchyma tissue (z), endocarp (En) composed of stone cells. B, spike showing bracts (o), young sessile fruits (d), and a mature fruit with long pedicel (e). C, longitudinal section of mature fruit showing pericarp (i), union (l) of seed and pericarp, large perisperm (k), small endosperm (m), which surrounds the embryo (E). D, flower diagram showing the position of the flower in reference to the rachis (a), bract (D), and pericarp (c), which surrounds the ovule (S).—After Meyer.

(Permission of Prof. Henry Kraemer.)

Stomata consist of pairs of crescent-shaped cells with an opening between them known as pores or stoma; they serve chiefly as means of ingress of carbonic acid gas, and by closing prevent or reduce transpiration, retaining their moisture.

Hairs and glands (secretory hairs) are elongated epidermal cells to which the velvety appearance of certain leaves and

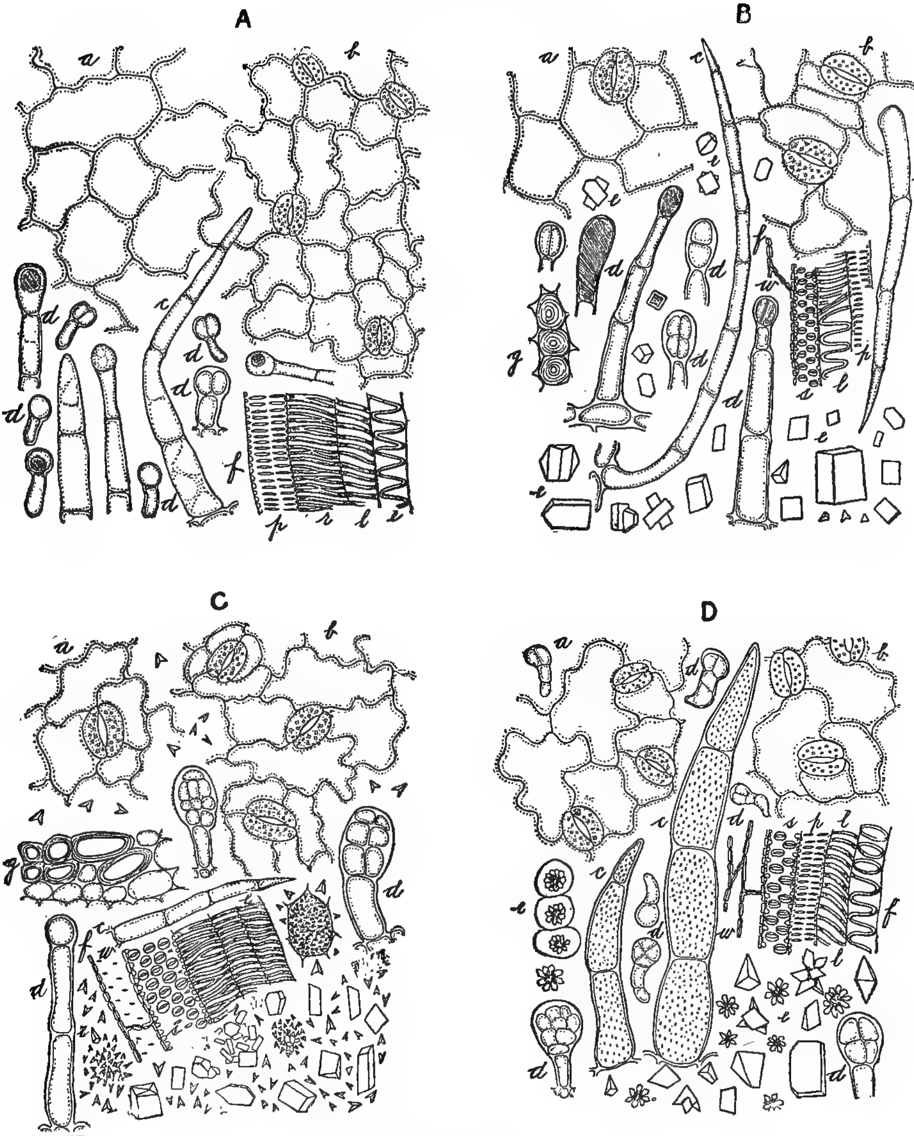

FIG. 87.

A, Digitalis; B, Hyoscyamus; C, Belladonna; D, Stramonium.—a, upper epidermis; b, lower epidermis; c, non-glandular hairs (which in stramonium are tuberculate); d, glandular hairs; e, calcium oxalate crystals; f, fragments of xylem showing tracheæ with bordered pores (s), reticulate markings (r), simple pores (p), spiral thickening (l), and wood fibers (w); g, bast fibers, which together with wood fibers are wanting in digitalis.

(Permission of Prof. Henry Kraemer.)

flowers are due. They present an endless variety of characteristic forms which are of aid in identifying leaves and blossoms, particularly in the powdered form. According to their develop-

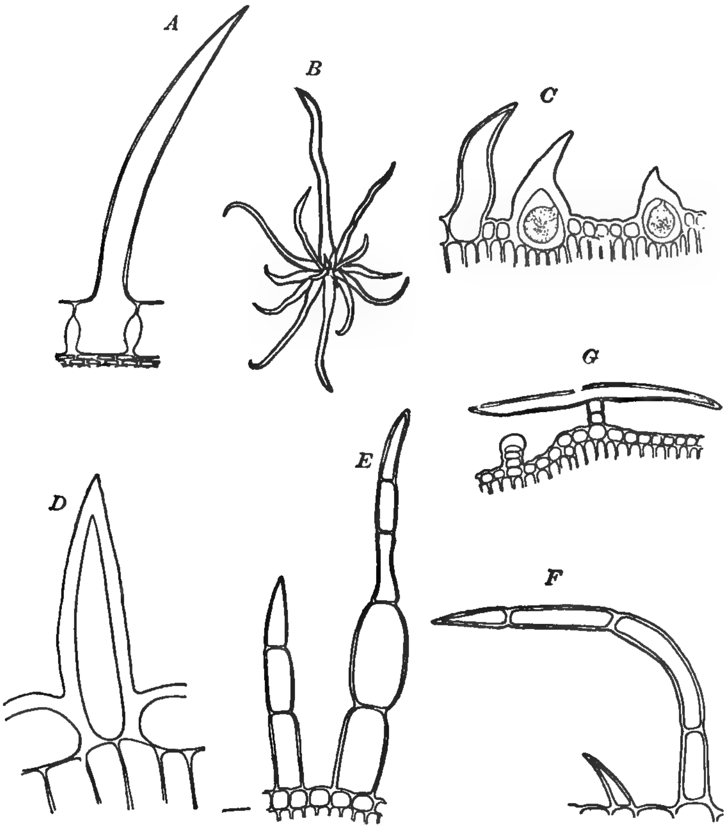

FIG. 88.—FORMS OF NON-GLANDULAR HAIRS.

A, hair from the epidermis of strophanthus; B, a hair from the capsule of *Mallotus philippinensis* (found in the drug known as kamala); C, hairs from the leaves and bracts of cannabis indica, two of them containing cystoliths of calcium carbonate; D, a hair from the under surface of the leaf of senna; E, hairs from leaf of digitalis; F, two forms of hairs from sage leaf; G, two forms of hairs from the leaves of wormwood (*Artemisia Absinthium*); a T-shaped non-glanular hair and a short glandular hair.

(Permission of Prof. Henry Kraemer.)

ment, these glands or hairs are termed puberulent (short, straight hairs), pubescent (longer hairs), pilose (long and straight), tomentose (long and matted), hispid (prickly), speriose (spines), and echinate (hooked).

The cell contents are made up of the living fluid matter called protoplasm and non-protoplasmic matter, which includes

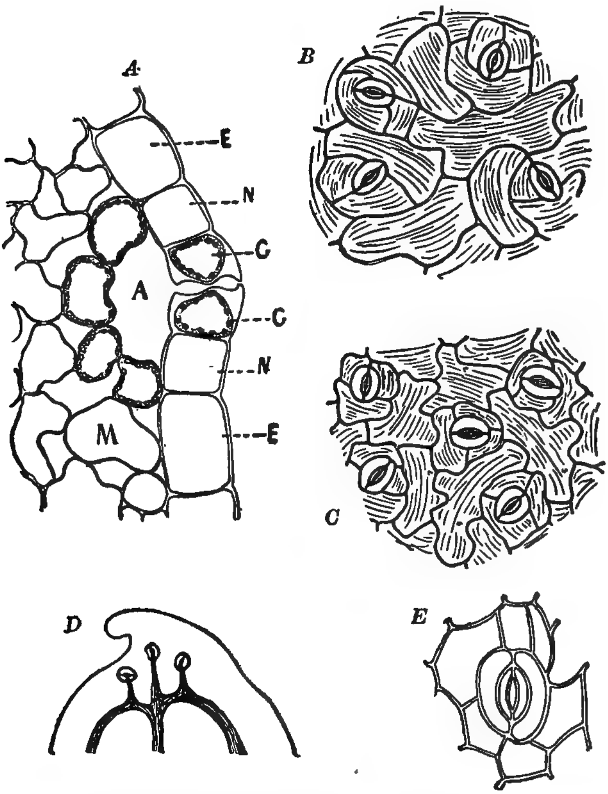

FIG. 89.—STOMATA AND WATER-PORES.

A.—Transverse section through lower surface of leaf of stramonium: stoma, with guard cells (G), containing cytoplasm, nucleus and chloroplastids; N, surrounding cells; A, intercellular cavity usually filled with cell-sap or watery vapor; E, epidermal cells; M, mesophyll. B.—Surface section of upper surface of leaf of *Viola tricolor* showing four stomata. C.—Surface section of under surface of leaf of *Viola tricolor* showing five stomata. D.—A section through the margin of the leaf of *Viola tricolor* showing a tooth with three water-pores. E.—A water-pore of *Viola tricolor* in surface section.

(Permission of Prof. Henry Kraemer.)

the various carbohydrates (starches, sugars), oxalate of calcium, chlorophyll, aleurone, tannin, oils, glucosides, alkaloids, resins, gums, etc.

With a knowledge of the morphology of plant organs in addi-

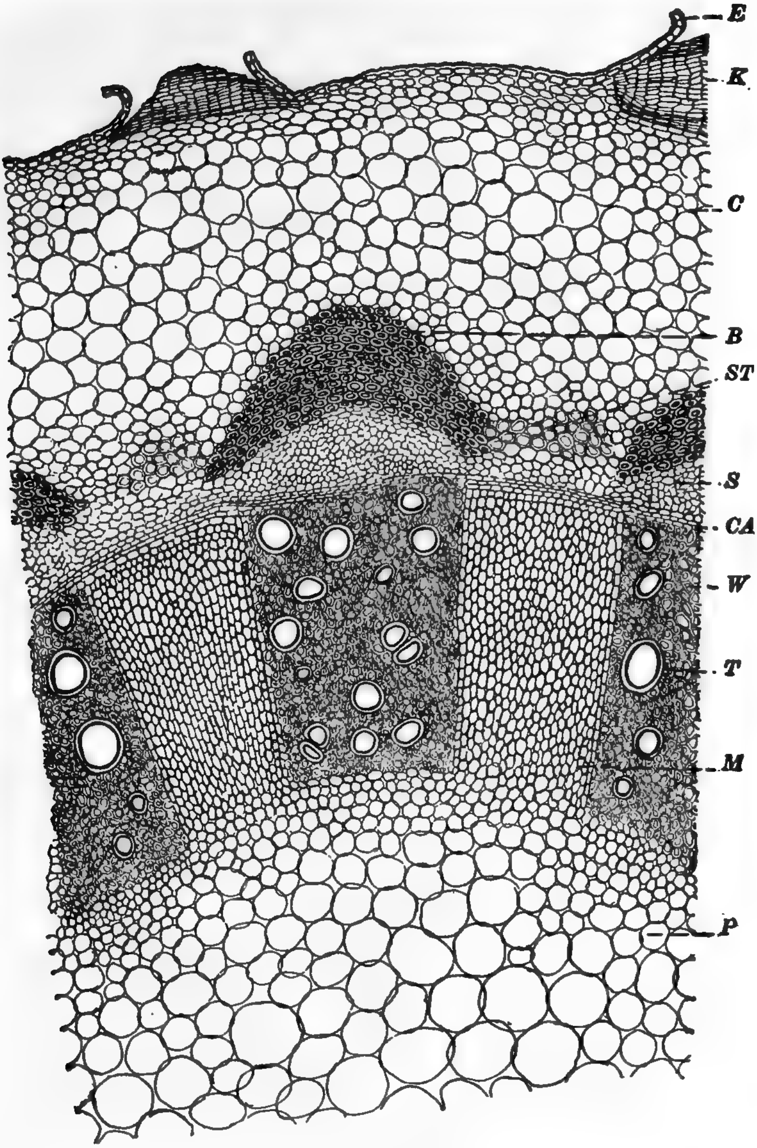

FIG. 90.—DICOTYLEDONOUS STEM STRUCTURE.

Transverse section through menispermum rhizome; E, epidermis, which is being replaced by cork (K); C, cortex; B, bast fibers; S, sieve; ST, stone cells; CA, cambium; T, ducts; W, wood fibers; M, medullary-ray cells; P, pith.

(Permission of Prof. Henry Kraemer.)

tion to their general physical characteristics, the pharmacognosist is able to identify botanic drugs, their substitutes and adulterants.

Powdered Drugs.—Far more complex are the problems to be solved in the identification of powdered drugs,* for the

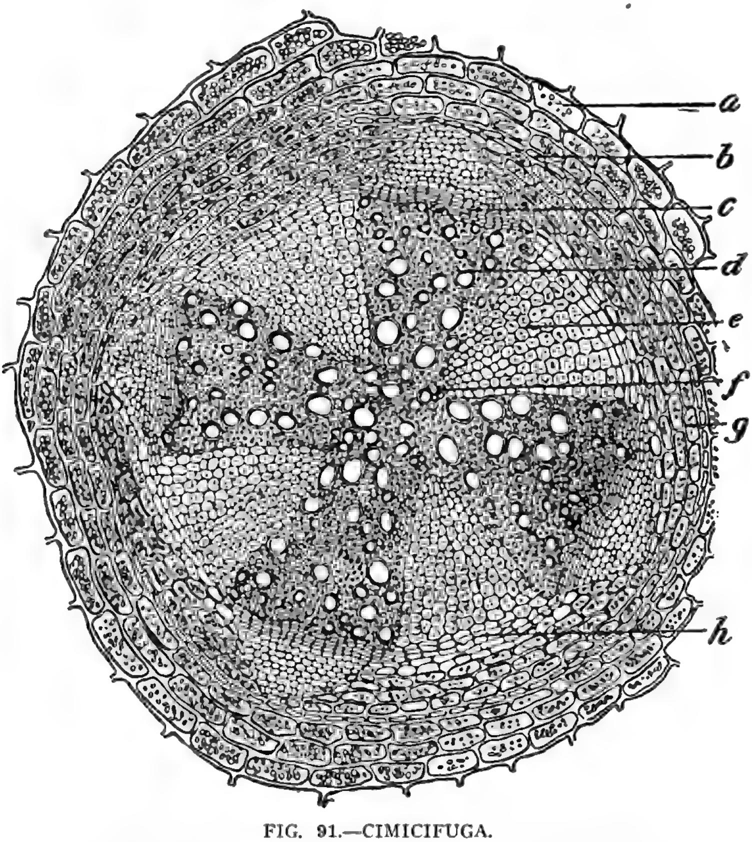

FIG. 91.—CIMICIFUGA.

Transverse section of the central part of a mature root in which the secondary changes are completed: a, parenchyma; b, endodermis; c, cambium zone; d, tracheæ in secondary xylem; e, broad, wedge-shaped medullary ray; f, outer portion of one of the primary xylem bundles; g, parenchyma beneath the endodermis; h, inter-fasicular cambium.—After Bastin.

(Permission of Prof. Henry Kraemer.)

process of grinding, powdering and sifting destroys to a great degree of morphologic characteristics of the drug; the finer the degree of comminution, the more difficult is the task of identification. It frequently happens, however, that long grinding fails

*See descriptive note at end of chapter.

to separate adjacent cell layers, as is usually the case with powdered fruits and seeds (spices). Thin walled parenchymatous cells are usually broken by fine grinding, permitting their con-

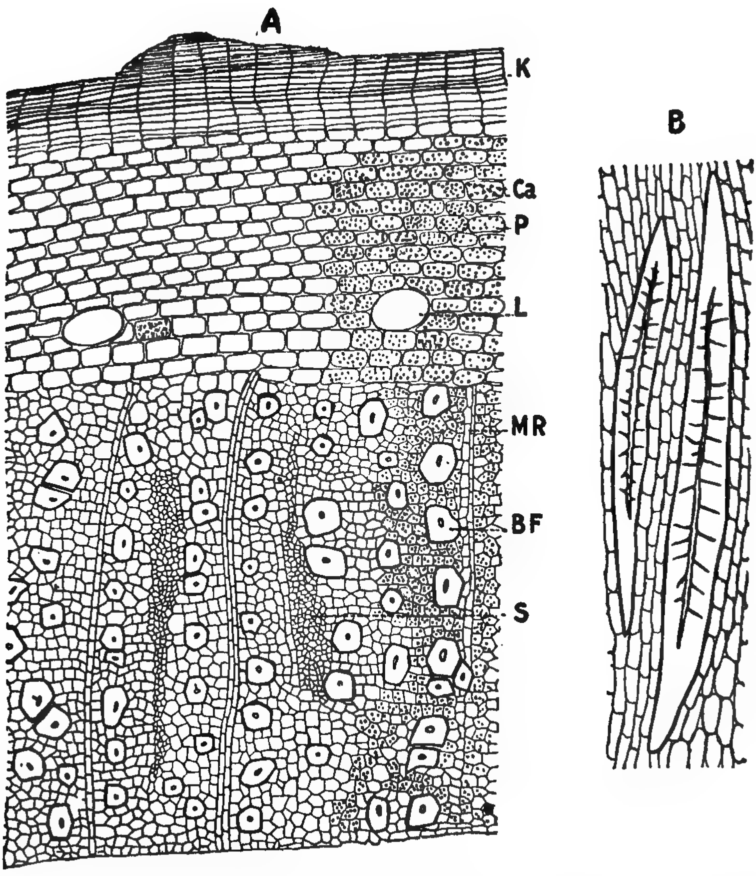

FIG. 92.
A, transverse section of red cinchona: K, cork; Ca, cryptocrystalline crystals of calcium oxalate; P, parenchyma containing starch; L, latex cells containing gum, resin and tannin; MR, medullary rays; BF, bast fibers; S, sieve. B, longitudinal section of same showing two bast fibers surrounded by parenchyma cells.
(Permission of Prof. Henry Kraemer.)

tents to escape. This sometimes misleads the investigator, because of the presence of isolated starch grains and calcium oxalate crystals. Fibers and tracheids are often broken into small fragments, yet each still retains its characteristics suf-

ficient for identification. Another great aid in microscopical identification is a knowledge of the structure of starch grains, which is characteristic for each and every variety of starch.

FIG. 93.

A mixture sold as ground black pepper: A, stone cells of olive endocarp; S, corn and wheat starch grains; B, stone cells of pepper hulls; C, fragments of seed coat and pericarp of cayenne pepper; L, crystals of calcium sulphate which separate on mounting the specimen in 25 per cent. sulphuric acid.

(Permission of Prof. Henry Kraemer.)

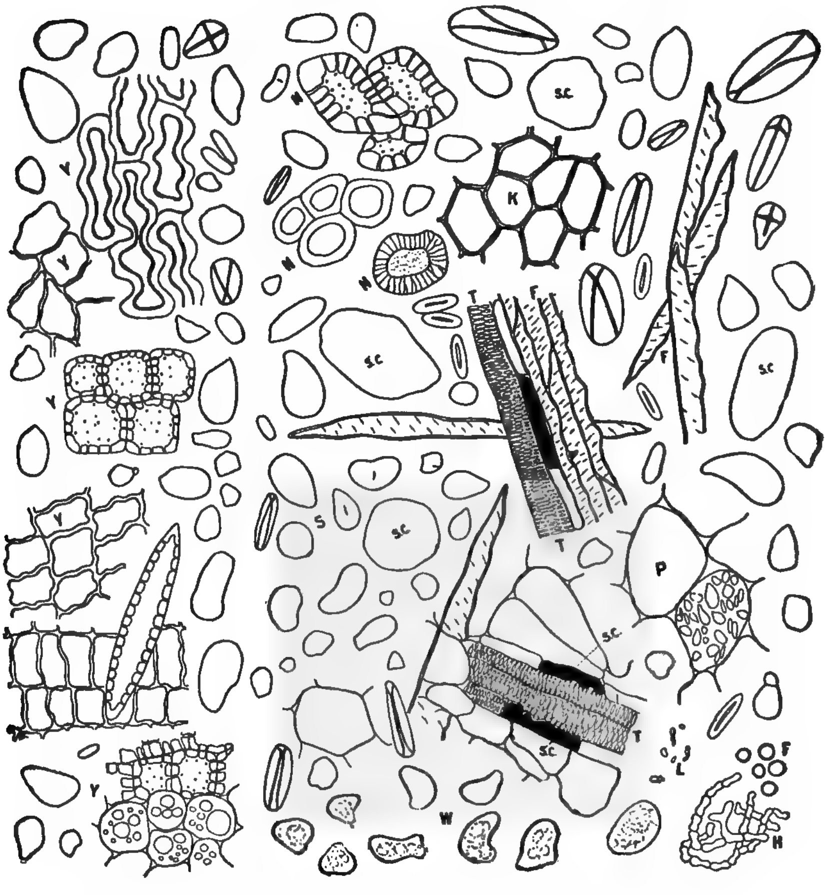

FIG. 94.—POWDERED GINGER CONTAINING FOREIGN TISSUES.

The following are the typical elements of ginger: F, *scleren-hymatous fibers* which vary from 0.3 to 1.3 mm. long and from 20 to 30 μ in diameter, the walls being somewhat undulate, about 3 μ thick, slightly yellowish, non-lignified, and having slender, oblique, simple pores; T, *reticulate tracheae* varying from 30 to 60 μ in diameter, the walls consisting mostly of cellulose, and with phloroglucin, giving but a faint reaction for lignin; SC, *secretion cells,* the walls of which are suberized and the contents of which in the fresh rhizome are oily and of a light yellow color, changing to golden yellow with sulphuric acid, whereas in the older commercial specimens the contents are yellowish, or reddish brown, balsam-like or resinous, becoming of a deep brownish black on treatment with sulphuric acid; K, *cork cells* which on an average are about 60 μ long and 25 μ wide; S, *starch grains* which vary from 20 to 60 μ in length, the largest being found in Jamaica ginger, have indistinct lamellæ, and do not polarize well unless mounted in a fized oil, as almond or olive; W, swollen starch grains; L, small, swollen, altered starch grains; P, *parenchyma* cells; H, F, hyphae and spores of a fungus, which are usually present in African ginger and easily detected in mounts prepared with sulphuric acid. In Calcutta ginger occur a large number of spherical starch grains resembling those of wheat, whereas in Japan ginger there are numerous compound grains. Adulterated ginger may contain fragments of tissues of Capsicum (Y), stone cells of endocarp of olive (N), or tissues of coap bark.

(Permission of Prof. Henry Kraemer.)

In addition to the usual methods of identifying starches based on the arrangement of concentric layers and their deportment towards various reagents, the application of polarized light with the microscope has become of great value in locating the position of the hilum. Thus, in granules with a certain hilum, the dark lines intersect, forming a cross; with an eccentric hilum the dark lines intersect so near one end as to form a V-shaped marking.

Valuation of Drugs by Chemical Methods.—Since the medicinal activity of all potent drugs resides in well-defined proximate principles, chemical assay methods enable us to accurately gauge not only their comparative therapeutic value, but also their quality—that is, in a measure, their freedom from admixtures.

These active principles are usually present in the drug, combined with a tannin or organic acid peculiar to the plant. For example, strychnin and brucin occur in combination with igasuric acid, aconitin with aconitic acid, cinchona alkaloids with cinchotannic acid, the 20 alkaloids of opium are combined as sulphates and acid meconates, cocain with cocatannic acid. It is therefore necessary, in the extraction of an alkaloid or glucoside from a drug, to employ an alkali in conjunction with a suitable (usually volatile) solvent, in order to liberate these principles from their natural combinations. The solution thus obtained contains alkaloids or glucosides, in addition to coloring and extractive matter. The separation of such crystalline principles in a state of purity, from the accompanying impurities, renders the operation slow and tedious. Quite a variety of assay methods have been proposed, but all are based on the same general principles, differing chiefly in details of manipulations. Most commonly employed is the method of Prollius, which consists in exhausting the powdered drug with a mixture of ether, chloroform, ammonia and frequently alcohol. This extract is then washed with several small portions of a diluted acid for the removal of the alkaloid, most of the coloring matter and extractive remaining with the volatile solvents. This acid solution, after making alkaline, is washed with ether or chloroform until all of the alkaloid has been extracted, then finally, after distilling off the solvent, the residue is estimated by residual titration, employing

decinormal acid and centinormal alkali V. S. The valuation of fluid or solid extracts or tinctures may be conveniently and accurately carried out by Lloyd's method, or its modified form proposed by Lyons.*

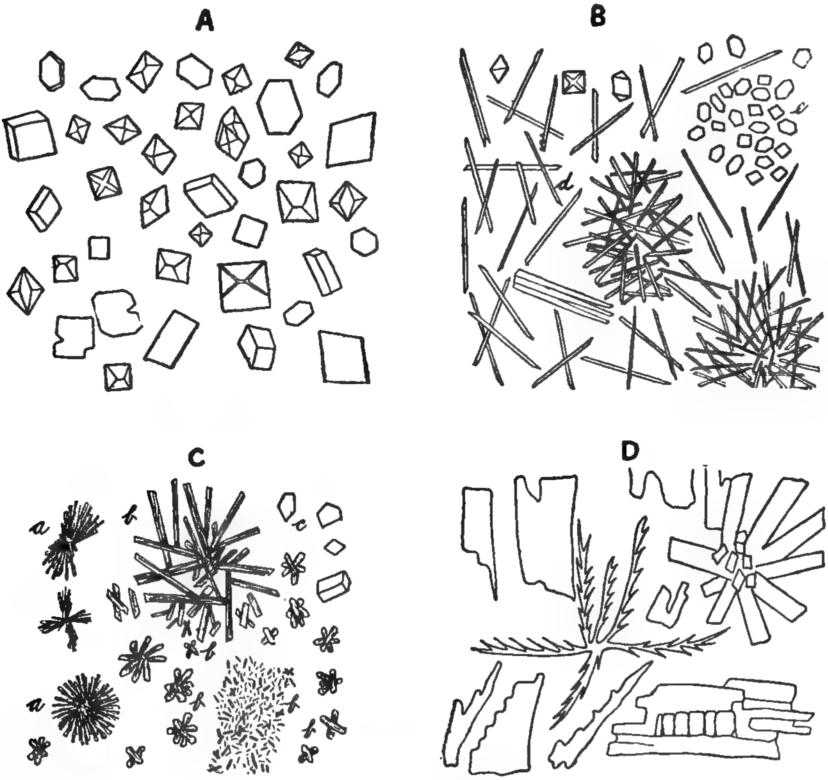

FIG. 95.—CRYSTALS FROM EXUDATIONS AND EXTRACTS.

A, crystals found in the residue after treatment of catechu with water; B, long prisms of catechin (d) found on treatment of gambir with chloral solution, the crystals soon dissolving, and prismatic plates (e) usually seen in glycerin mounts of gambir; C, crystals from aloes, including aloin (a), broad prisms (b) from Barbadoes aloes, and plates (c) from Cape aloes; D, crystals of benzoic acid obtained by subliming benzoin on a slide or in a watch crystal.

(Permission of Prof. Henry Kraemer.)

The extract (ether, chloroform, or petroleum) of the drug is washed with acidulated water until all of the alkaloid has been removed; after washing the acid extracts with ether for re-

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*Merck's Report, 1900, p. 61. For details consult "Handbook of Practical Assaying of Drugs and Galenicals," by A. B. Lyons, Nelson and Baker, Detroit.

moval of colors, this solution is finally made alkaline and the precipitated alkaloid extracted by shaking with ether or chloroform. The mixed washings may be weighed after evaporation of the solvent or, more usually, estimated by titration.

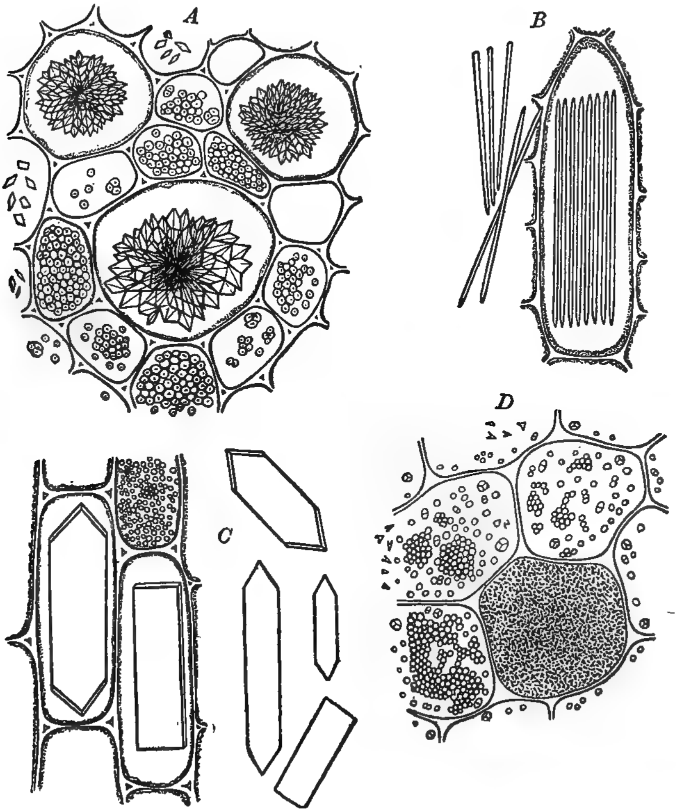

FIG. 96.—FORMS OF CALCIUM OXALATE CRYSTALS.

A, transverse section of rheum showing rosette aggregates of calcium oxalate in three of the cells and starch grains in some of the others; B, longitudinal section of scilla showing raphides; C, longitudinal section of quillaja showing large monoclinic prisms and pyramids of calcium oxalate and also some starch grains; D, transverse section of belladonna root showing one cell filled with cryptocrystalline crystals, the remaining cells containing starch.

(Permission of Prof. Henry Kraemer.)

*The Essential Oils.**—Whether used in perfumery, by the confectioner, or in medicine, the volatile oils are first and usually judged by appearance, odor and taste. Since, however, such

*Guildemeister & Hoffman, "Die Aetherische Oele," Springer, Berlin. Also English Translation; "Chemistry of Essential Oils and Artificial Perfumes," Parry, London.

standards of the experts are indescribable and must vary with the individual, a great variety of physical and chemical tests have been introduced. With the introduction of the latter classes of tests, many difficulties have been encountered, because of the complex nature of the majority of the volatile oils, the flavor or odor residing in two or more principles, and also variations due to influences of climate, season, soil, cultivation, relative humidity, etc., which cause qualitative and quantitative differences from year to year. Finally, there are changes due to exposure to light and air. As a result of these unavoidable fluctuations, considerable latitude among the physical constants and tests must be expected and permitted. As a result of this, adulteration is extensively and so skilfully practiced, that at times the expert is at a loss to distinguish the adulterated from the true. In some instances, the detection of adulteration is almost impossible; as the presence of methyl salicylate in oils of wintergreen or birch, benzaldehyde in oil of bitter almond, or geraniol in otto of rose. Such crude additions as oil of turpentine or kerosene or the oils from other parts of the same plant are readily detected through the usual chemical and physical tests.

Another practice extensively employed consists in withdrawing the odorous or flavor-bearing constituent, partly or entirely, from an oil, as is the case with such oils as anise, fennel, lemon, sassafras, thyme and peppermint. Sufficient of such constituents are left in the oils to impart the necessary odor or flavor. The detection of this practice is carried out by a quantitative estimation of the active constituent.

The following tests are of general application:—specific gravity at 15° or 25° C., optical rotation, fractional distillation; congealing point determined by the Beckmann cryoscopic apparatus, and noting the maximum rise of the thermometer upon crystallization, applicable among the oils of the umbelliferæ; solubility in alcohol of 90, 80 and 70 per cent. (vol.). According to the relative percentage of terpenes present in the oil, the solubility varies; thus, if an oil which is soluble in a certain volume of alcohol under normal conditions does not dissolve, it is possible to draw conclusions as to the nature and quantity of the adulteration present. In this manner, additions of oil of turpentine, or an oil rich in terpenes or kerosene, may be de-

tected. "Solubility value"* is determined by dissolving 5 cc. of an oil in 10 cc. alcohol of sp. gr. 0.799 and diluting with water until the solution becomes turbid, then on multiplying the number of cc. of water by 100 the "solubility value" is obtained. The "acid number" expresses the numbers of mgm. of potassium hydroxide required to neutralize the free acid contained in 1 g. of the oil. The "ester number" expresses the number of mgm. of alkali required to saponify the ester contained in 1 g. of the oil. Special methods adapted to the quantitative valuation of oils cover a wide field since they embrace the estimation of most every class of organic bodies. As examples of these classes, we may cite the determination of aldehydes in oils of lemon, citronella, cinnamon and bitter almond; alcohols in oils of citronella, sandalwood, Indian geranium and peppermint; phenols in oils of clove, allspice, bay and thyme; esters in oils of bergamot and lavender; esters in oils of anise, carraway, fennel, and so on.

Since the majority of essential oils represents complex mixtures of hydrocarbons and oxygenated compounds, of which there are a great variety, and also since these oils differ essentially from one another qualitatively and quantitatively, each individual presents a problem in itself. Hence, aside from the general methods detailed above, the more accurate assay processes must necessarily differ according to the chemical characters of the constituents of the oil in question.†

Pharmacologic Valuation of Drugs.‡—Under Pharmacology, we understand the study of changes induced in the living organism by the administration, in a state of minute sub-division, of such unorganized substances as do not act merely as foods (Cushny).

Medicinal substances produce a specific pharmacologic action because of their chemical affinity for certain kinds of protoplasm. "Since the functions of the various parts of the body depend upon the lability of the protoplasm of the cells composing them, we naturally infer that when some other substance combines

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*Dowzend, *Chem. & Drug.*, LIII., 749.

†Methods of assay are detailed in the U. S. Pharmacopœia; Guildemeister and Hoffman; and the "Semi-annual Reports," issued by Schimmel & Co., Leipzig (Fritsche Bros., New York).

‡"Pharmacologic Assay of Drugs." E. M. Houghton, *Merck's Report*, 1900. 315.

with this protoplasm, the normal physiologic processes will be altered." Thus, small doses of strychnin increase the reflex excitability of the central nervous system, while large doses may so excite the activity of the nerve cells that the slightest stimulation is followed by tetanic convulsion. The greater the dose, the greater is the deviation in the functional activity from the normal. The function of a given organ is altered in degree but not in kind, when under the influence of a drug—that is, the action of drugs is quantitative and not qualitative. The physiologist who studies the effect of medicinal agents upon healthy animals can therefore furnish very accurate data relative to the action of these on various organs. The practicing physician, with such data, can intelligently prescribe drugs and expect results. The next question from the prescriber is, "How can I combat disease if I am furnished with preparations of drugs which are not of uniform pharmacologic activity?" Also, can all botanic drugs and their preparations be standardized? Chemistry has solved this question but partially. Many drugs owe their medicinal action to certain well-defined alkaloids or glucosides, as opium, nux vomica, cinchona or coca, and in such instances a quantitative assay carries with it a guarantee upon which the physician may depend. On the other hand, there are many other drugs in which an assay is of little value owing to the lack of means whereby we may distinguish potent and inactive forms of the active principles, as exemplified in the aconites, digitalis, ergot and veratrum viride, etc. Some of these contain several active principles, and the physiologic action of one may be antagonistic to the other; thus digitalis contains several glucosides, crystalline and amorphous. One found in the aqueous infusion of the drug is a diuretic, while others, present in the alcoholic extracts, are heart stimulants; while still others are more or less indifferent.

In certain plants, as, for example, ergot, cannabis indica and strophanthus, a chemical assay is of little or no value owing to the sensitive nature of the active constituents which undergo decomposition when treated with the reagents necessary for their extraction. In certain other drugs, whose activities reside in one or more crystalline, non-crystalline or resinous principles, as rhubarb, taraxacum and sarsaparilla, grindelia,

senna, phytolacca, pomegranate and many others, an assay is of no value. Therefore, a physiologic standardization is the only solution of this problem when chemical assay fails.

As this subject is so complex that a wrong impression might be given by a too abbreviated account, those who are interested may consult the works of reference here given. Before arriving at any opinion, however, it would be always safe to take the advice of one trained *by long experience* in this kind of work:

Pharmacognosy and Botany. U. S. Dispensatory, Lippincott Co., Philadelphia.
Botany and Pharmacognosy, Kraemer, Philadelphia, 1907.
Introduction to Pharmacognosy, Jelliffe, Philadelphia, 1904.
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Pharmacognosicher Atlas, Moeller, Berlin, 1892.
Leitfaden zu Mikroscopisch-pharmakognostichen Uebungen, Moeller, Wien, 1901.
Anatomischer Atlas d. Pharmkognosie, Tschirch, Leipsiz, 1900.
Angewandte Pflanzenanatomie, Tschirch, Leipzig, 1889.
Vegetabilischen Nahrungs und Genussmittel, Vogel, Berlin, 1889.
Die Rohstoffe des Pflanzenreiches, Wiesner, Lepzig, 1903.

Microscopy of Drugs and Foods.
Microscopy of Vegetable Foods, Winton, New York, 1906.
Microscopical Examination of Food and Drugs, Greenish, London, 1903.
Anatomical Atlas of Vegetable Powders, Greenish, London, 1904.
Grundlagen, Methoden für Microskopische Untersuchung von Pflanzenpulvern, A. Meyer, Jena, 1901.
Mikroskopie der Nahrungs und Genussmittel der Pflanzenreiche, Moeller, Berlin, 1886.
Valuation of Vegetable Drugs and Foods, Kraemer, *Merck's Report,* Jan., 1900. et seq.
Analytical Scheme for Microscopical Examination of Powd. Drugs, B. E. Nelson, *Merck's Report,* 1900.

Reagents and Microscopical Technique.
Behrens, Guide to the Microscope in Botany, Boston, 1885.
Chamberlain, Methods in Plant Histology, Chicago, 1901.
Zimmerman, Botanical Microtechnique, New York, 1901.

CHAPTER XI

HABIT-FORMING AGENTS.*

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Notwithstanding the fact that legislation, federal, state and territorial, adverse to the indiscriminate sale and use of opium has been enacted during the past decade, and most physicians are using greater circumspection than formerly when prescribing opium, its preparations and derivatives, the amount of opium (exclusive of smoking opium, which is now denied entry into this country), consumed in the United States per capita, has been doubled within the last forty years. Not only has there been this increased consumption of opium, its preparations and derivatives, but large quantities of other habit-forming agents, introduced chiefly for medicinal purposes, have been used. For example, "cocain"† (cocain hydrochloride) has been used for about 25 years, and the amount consumed at present is estimated at approximately 150,000 ounces per annum. In addition, it is well known that large quantities of acetanilid, acetphenetidin, antipyrin, phenacetin, caffein and chloral hydrate, and smaller amounts of codein, dionin and heroin are consumed. It should be noted that the amount of opium imported into the United States so far during the present decade indicates that the amount per capita is about the same as for the preceding ten years. Deterrent factors are undoubtedly anti-narcotic legislation and publicity.

There are at present at least 100 sanatoriums advertising treatment for drug addiction, and it is well known that many thousands of cases are treated annually by physicians in private practice and general hospitals. The writer knows of at least 30 so-called mail-order "drug-addiction cures," some of which apparently have a large patronage. The manager of one of these

*By permission of the U. S. Department of Agriculture, Washington, D. C.

†The words "cocain," "codein" and "morphin," as used in this chapter, refer to the salts of the respective alkaloids.

treatments stated that his company had 100,000 names, including alcohol addicts, upon its books. The number of drug addicts in the United States is variously estimated by those who are conversant with the situation at from 1,000,000 to 4,000,000; the latter number is probably excessive.

During the last ten years the writer has examined hundreds of preparations containing one or more habit-forming agents, exclusive of alcohol. It was not an uncommon practice in former days to represent to the consumer that such agents were absent, when as a matter of fact the very drugs named in the disclaimer were present. The reason for this subterfuge is plain. Normally no one desires to take preparations containing known habit-forming agents, which are frequently responsible for the use of, or demand for, the preparations containing them. During the last few years both Federal and State laws have been enacted requiring a declaration on the label of the quantity or proportion of certain habit-forming agents when present in remedies intended for the treatment, mitigation or prevention of disease in man or animals, but the consumer in many instances is not sufficiently conversant with the deleterious and harmful nature of these agents to avoid them. Again, these pernicious drugs are present in products which may not be classed as medicines within the meaning of the above definition.

It is our purpose here to consider (1) representative preparations, which, in all probability, dispose to habit formation; (2) preparations known to produce drug addiction; (3) nostrums laden with habit-forming agents to be used in treating drug addicts, including those addicted to the tobacco habit; (4) those who are primarily responsible for their sale and use; and, lastly, (5) some measures which will minimize or tend to eradicate the evil. The several classes of products will be considered as nearly as practicable in the order in which they are used, from infancy to old age. Limited space and a desire to speak only from positive knowledge admits consideration of only the most commonly used and known products of each class.

Soothing sirups naturally occupy the first place in such a list, which includes baby sirups in general, "colic cures," "children's anodynes," "infant's friends," teething concoctions, etc. It has long been known to the medical profession that these

products as a rule contain habit-forming agents, but the majority of mothers have been and still are, ignorant of this fact, although some degree of publicity has been given the matter during recent years. Lest any suspicion or fear should be aroused in the mind of the mother by the fact that the presence of opinion, morphin, chloroform, cannabis indica, or some other harmful agent is declared upon the label, the manufacturer or dealer endeavors to allay such fear by statements of the following character: "Contains nothing injurious to the youngest babe"; "Mothers need not fear giving this medicine to the youngest babe, as no bad effects come from the continued use of it." Statements of the following character were also made in connection with preparations containing morphin or opium, or both, before the Food and Drugs Act went into effect: "This valuable remedy does not contain any opium, morphin, laudanum or paragoric," and "It is free from all harmful agents."

Statements of this character have been largely eliminated, but in some instances they still appear in modified form either on the package itself, in the accompanying circular or in masked form in newspaper advertisements. Notwithstanding the fact that these representations have been eliminated or modified so as to comply with the letter of the law, mothers, because of past representations and the fact that the false impressions left by them have not been corrected, believe that these soothing remedies are neither harmful nor habit-forming, and therefore give them with a certain feeling of security, with the result that in some instances the baby is put to sleep never to awake again. Numerous cases of this character are on record. In some instances, in which the remedy is freely used and the child does not succumb, there is developed a case of infant drug addiction. As soon as the effects of one dose passes away, the child becomes irritable and fretful, with the result that another dose is administered, the craving is met, and the child is quieted, a condition which is analogous in every respect to drug addiction among adults. Sometimes these children look plump and healthy, but as a matter of fact their flesh is soft and flabby and they withstand attacks of illness very poorly. The chief active agents of soothing sirups are well known to be opium, morphin, heroin,

codein, chloroform and chloral hydrate in some combination.*

It is hardly believable that anyone, for the sake of a few dollars, would concoct for infant use a pernicious mixture containing cocain, but several such mixtures have been found during the last year. One was offered for importation, under the name of "Espey's Syrup for Children's Dentition," which contained one-half grain of cocain hydrochloride to each bottle of about 1 ounce. The injuriousness of this product was sufficient ground for prohibiting its importation into the United States. Another element of danger in the use of soothing sirups is the fact that nurses often use them, unknown to mothers, for putting children to sleep. Several well-known soothing sirups, it is reported, have been introduced largely by nurses in this manner.

Soothing sirups containing habit-forming agents, used without discrimination, undoubtedly leave their impression on the delicate organisms of infants and induce tendencies which under unfortunate circumstances in future life may be aroused to activity and develop an evil habit of one form or another. The question arises: How is this condition to be met? The signs of the times point to two ways, namely, education and the withdrawal of the dangerous articles, both measures appearing to be necessary. At present there are on the market, intended to be used for children, several mixtures free from the customary habit-forming agents, but they apparently do not give satisfaction as formerly, as manufacturers are constantly receiving calls for the "old kinds."

During the last twenty years a large number of soft drinks containing caffein and smaller or greater quantities of coca leaf and kola nut products have been placed upon the market. Preparations of this class, on account of insufficient information, were formerly looked upon as harmless, but they are now known to be an impending evil. Centuries before cocain was introduced as a remedial agent, wonderful accounts of the energy-creating

*The following are representative of this class:
Children's Comfort (morphin sulphate).
Dr. Fahey's Pepsin Anodyne Compound (morphin sulphate).
Dr. Fahrney's Teething Syrup (morphin and chloroform).
Dr. Fowler's Strawberry and Peppermint Mixture (morphin).
Dr. Groves' Anodyne for Infants (morphin sulphate).
Hooper's Anodyne, the Infant's Friend (morphin hydrochlorid).
Jadway's Elixir for Infants (codein).
Dr. James' Soothing Syrup Cordial (heroin).
Kopp's Baby's Friend (morphin sulphate).
Dr. Miller's Anodyne for Babies (morphin sulphate and chloral hydrate).
Dr. Moffett's Teethina, Teething Powders (powdered opium).
Victor Infant Relief (chloroform and cannabis indica).
Mrs. Winslow's Soothing Syrup (morphin sulphate).

properties of coca leaves were chronicled. The phenomenal endurance attributed to the Peruvians and others was often ascribed to the stimulating effects produced by the chewing of coca leaves, and this idea has been widely exploited. It is believed to some extent at present that the use of cocain taken internally produces a sense of exhilaration, and the amount of muscular and mental power appears to be temporarily increased. Impetus was given to this belief by the enthusiastic reports of the virtues of this drug, published not only in medical literature but in the secular press as well. Cocain is one of the most insidious and dangerous habit-forming drugs at present known. Many lives have been wrecked and many crimes have been committed as a result of its use, and strenuous efforts are being made to curtail its employment. The amount present in certain soft drinks is small, to be sure, but such an insidious, habit-forming drug certainly has no place whatever in these products. The presence of tropococain, an ally of cocain, has also been established. Not only is it most pernicious to add cocain to soft drinks in any quantity (usually in the form of coca leaf extract), but even the use of coca leaf extract so manipulated as to reduce the amount of cocain, or eliminate it altogether, must still be looked upon as a questionable practice, because any product or name which would suggest the presence of cocain or its allies, by taste or otherwise, must have a baneful influence. It is known that very small amounts of morphin or cocain, or even a suggestion as to their presence, will tend to destroy the equilibrium of reformed addicts and bring back the former craving.

The cola nut was prominently brought forward about twenty-five years ago as an agent for the relief of fatigue, but in this respect it has been a disappointment. For some time it was thought that the nut possessed some peculiar substance which accounted for this characteristic, but searching investigations showed that its chief active agent is caffein. Whatever virtue the drug possesses, therefore, appears to be due largely, if not solely, to this constituent. In fact, at present mixtures of caffein and burnt sugar are extensively used in preparing various caffein-bearing soft drinks, instead of the kola nut and its extracts. The caffein used is derived chiefly from waste tea leaves. The virtues of coca leaves and kola nuts have been exploited together, and it

was only natural that they should be combined in preparations which would represent the purported virtues of both. Such combinations were made with the result that quite a number of so-called soft drinks now on the market contain both of the habit-forming agents, cocain and caffein. It is not uncommon to find persons addicted to the use of medicated soft drinks. It is also a well-known fact that many factory employees, stenographers, typewriters, and others subject to mental or nervous strain spend a large part of their earnings for drinks of this character. In pass-

FIG. 97.—EXAMPLES OF MEDICATED SOFT DRINKS.

ing it may be of interest to note that life insurance companies are considering the status of soft-drink habitués as future risks.*

Various arguments have been advanced in justification of the use of caffein and the extract of coca leaves, treated or otherwise, in soft drinks. It is well known that parents, as a rule, withhold tea and coffee from their children, but having no knowledge of the presence of cocain, caffein or other deleterious agents in soft drinks, they unwittingly permit their children to be harmed by their use.

*A partial list of medicated soft drinks containing caffein, extract of coca leaves, extract of kola nut, etc., will be found in Senate Document No. 644, page 372, of the Sixtieth Congress, second session.

On account of their frequency, prominence and difficulty of satisfactory treatment, diseases of the nose and lungs have received special consideration, not only by the best medical talent but also by charlatans entirely ignorant of the subject. The number of remedies concocted for the treatment of these afflictions is legion. Their vaunted values are, as a rule, dependent upon the presence of certain powerful drugs, such agents as cocain, chloral hydrate, codein, heroin, morphin, opium and tobacco being present. Most prominent among the diseases for which such remedies are offered are asthma, catarrh, colds, coughs, consumption and hay fever.

FIG. 98.—CATARRH "CURES" CONTAINING COCAIN.

Previous to the enactment of State and Federal laws requiring the declaration of cocain, these concoctions enjoyed large sales.

The exact cause of asthma is not definitely known by the medical profession at present. There is no known treatment which will eradicate the disease. The sufferer, however, is anxious to pay any price within his power to be freed from his infirmity, or at least to be relieved, which is the most that can be done by the most skillful physician. Notwithstanding this fact, numerous preparations are on the market which have in the past been represented as "cures," "infallible cures," "positive cures" and "specifics" for asthma, and these misrepresentations are still used in literature apart from the package, and most advertisements in newspapers, magazines, etc. Most of them consist of well-known substances in various proportions, among which are belladonna,

stramonium, lobelia, potassium nitrate, potassium iodide, etc. There are, however, a goodly number exploited at present which have as their basic agents cocain, morphin, opium or chloral hydrate. An example of the cocain type is "Tucker's Asthma Specific," which consists of a solution of cocain, and is sold throughout the United States as a result of extensive advertising and personal recommendation. The "Asthma Specific" consists of a bottle of medicine containing cocain, to be used as a spray with an atomizer. The price of the latter is $12.50. Recent investigations show that the amount of cocain purchased by the promoter of this remedy from a single manufacturing house during four months varied between 256 and 384 ounces a month.

It is true that the amount of cocain introduced into the nose by means of a spray is small, but it is well known that exceedingly small amounts are required, when used in this manner, to produce constitutional effects. In fact, this is the popular manner in which cocain is taken by those addicted to its use. They are commonly known as "sniffers" or "coke sniffers" because of the fact that the cocain is sniffed into the nose.

Another instance brought to the writer's attention was the selling of cocain for the same purpose by a registered physician, who maintained that he had the right to send his treatment, as he called it, consisting essentially of cocain hydrochloride, into interstate commerce to asthmatics and other persons similarly afflicted, without in any manner indicating upon the label of the package the fact that the preparation contained this injurious habit-forming drug.

Under existing laws, it is practically impossible to reach physicians engaged in practices of this character, provided they declare the presence of certain habit-forming drugs on the label and refrain from making false or misleading statements, for the reason that the State laws are so worded as practically to exempt physicians, and unfortunately there are a considerable number engaged in such dealings. If physicians of this type do not actually engage in the practice, they affiliate with some company or institution which is engaged in the business and in this way shift the responsibility and thus relieve themselves from liability under the present laws.

"Ascatco," an opium-arsenic preparation, represented as an Austrian product, is also largely used as a remedy for asthma and similar afflictions and enjoys a large sale. Another interesting treatment is known as "Davis' Asthma Remedy," put on the market by a dealer in real estate. The active agent of this commodity is chloral hydrate, of which each dose contains from 1 to 8 grains. According to the directions: "Dose can be increased or diminished or taken as often as needed. If necessary, take as many as three doses all within fifteen minutes. Adults can repeat as many as eight times in succession." On the label appears the following: "Tell others how it benefits you after using it." The conditions here are most propitious for the formation and spreading of the chloral habit. These examples give an idea of the character of the remedies at present being exploited for asthma.

The remedies offered for asthma are, as a rule, advertised for the treatment of catarrh also, but certain special remedies have also been devised specifically for the treatment of this condition. These contain the same habit-forming drugs, the usual one being cocain. Previous to the enactment of State and Federal laws requiring the declaration of cocain when present in a commodity, such products as Dr. Birney's Catarrh Powder, Dr. Agnew's Catarrh Powder, Dr. Cole's Catarrh Cure, Crown Catarrh Powder, etc., enjoyed large sales. A number of States, however, passed laws forbidding the sale of this class of mixtures except on physicians' prescriptions. It should be noted in this connection that the "catarrh cures" enumerated are, from the names, ostensibly devised by certain physicians, but there are good reasons for believing that no doctor of medicine has ever been connected with the introduction or promotion of these remedies. Several States required these concoctions to be marked "Poisons," which had a certain deterring effect. Many of the laws, however, were violated through some technicality, or rendered ineffective in other ways.

One of the conditions defeating the enforcement of the State laws was the fact that these pernicious products could be shipped in interstate commerce, without any information relative to the presence of cocain, to the addicts themselves or any other irresponsible person. When the federal Food and Drugs Act was

passed, it was apparent that products containing cocain or cocain derivatives must bear a statement on the label of the quantity or proportion contained in each ounce of the material, if shipped in interstate commerce or manufactured and sold in the District of Columbia or in territory subject to the jurisdiction of the United States. The result has been that most of these cocain-laden mixtures have been either taken off the market, sold locally, or shipped in interstate commerce by and through irresponsible persons. In some instances they are sent directly to the drug habitués by so-called reputable dealers. For example, a clergyman interviewed the writer some time ago as to the possibility of taking action against a certain firm supplying his communicants with a "catarrh powder," formerly known under the name of "Dr. Agnew's Catarrh Powder." He stated that the use of the powder was ruinous to some of his congregation and furnished the writer with the name of a large wholesaler in an adjacent State who furnished the remedy. A letter was written to this firm asking whether it would furnish Dr. Agnew's Catarrh Powder; and if so, what the charges would be. The firm was also advised that the reason for making the application was that the laws of the District of Columbia were so stringent and so rigidly enforced that it was exceedingly difficult, if not impossible, to purchase any cocain or cocain preparation in this jurisdiction. The firm in question responded to the effect that the desired article would be sent at a certain price. The amount named for three packages was transmitted by postal order and three packages of Dr. Agnew's Catarrh Powder were duly received.

Another case was that of a boy who had contracted the cocain habit. His father made inquiry as to whether it was possible for the federal authorities to interdict the sale of this commodity. He stated that in his home city the article was freely sold, and his son being known as a habitué, it was offered to him continually. The boy, about 18 years of age, stated that it was simply impossible for him to resist the temptation, and in order to save the family from disgrace he requested that he be sent into a country where cocain could not be purchased. He was accordingly sent to Germany, where he was at the time of the father's interview with the writer. It was also stated that the habit was contracted by the injudicious use of cocain in the treat-

ment of catarrhal conditions by a reputable and well-known specialist. The father was anxious to bring his boy back to America, but was afraid to do so, owing to the ease with which this dangerous drug could be obtained.

The medical profession, state boards of health, pharmacy boards, and others interested in the public welfare have instigated what might be considered a crusade against the indiscriminate sale of cocain or mixtures containing it, but, owing to the fact that there are many individuals in the country who are more interested in the dollar than in the welfare of mankind, there are many ways found of evading the laws. For example, the druggist is not restricted in his purchases of cocain, and there is no law except in a few States requiring him to keep a record of the amount of cocain he handles in any given period of time. The result is that some druggists surreptitiously dispose of cocain to persons known to be addicted to its use, or others introduced to him by "cocain sniffers." These victims are well aware that if they give information of any character relative to their source of supply it will be cut off immediately, and the result is that the druggist can sell the commodity in this way with comparative security. Men who do this are in the same class as saloon-keepers who sell liquors to confirmed drunkards.

Another source of difficulty is the so-called "morphin and cocain doctor." The laws permit the prescribing of these agents by doctors in their regular practice and to known drug habitués at their discretion or as the case may demand. The result is that in some cases there is little conscientiousness exercised in giving these prescriptions, and some doctors will write a large number of them for 25 cents each.

The ingenuity and cunning of peddlers of cocain is astonishing. For example, one was discovered carrying about a supply of morphin and cocain in a book hollowed out for the purpose. The edges of the leaves and one of the covers were glued together, and the body of the pages cut out, thus leaving a book-like box, which was innocent looking and well adapted for the business.

Colds and coughs are among the most common ailments of childhood and youth, and many special mixtures have been de-

vised and placed on the market for treating them. These concoctions usually contain one or more habit-forming drugs.*

The same habit-forming agents are offered to the public in the form of confections under such names as cough lozenges and pastiles.†

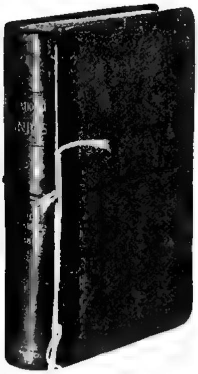

FIG. 99 FIG. 100

FIG. 99.—BOOK-BOX FOR SURREPTITIOUSLY PEDDLING MORPHIN
FIG. 100.—VIEW OF THE INTERIOR OF THE SAME.

Efficient cough and cold remedies can readily be prepared without the use of pernicious drugs. The legion of ubiquitous headache mixtures are also exploited for these ailments.

The exploiting of so-called consumption cures has apparently always been an inviting field to quacks. Promoters of these remedies are lavish in advertising them as positive and infallible cures. From the nature of the disease and the general information available to the public, it is only natural that persons so afflicted should grasp at the last, or any, straw. These remedies as a rule contain one or more of the well-known habit-forming agents, the action of which is to benumb the sensibilities and thus make coughing and some of the other symptoms less promi-

*This is clearly shown by the following examples:
Acker's English Remedy (chloroform).
Adamson's Botanic Cough Balsam (herein hydrochloride).
Dr. A. Boschee's German Syrup (morphin).
Dr. Bull's Cough Syrup (morphin, later codein).
Dr. Fenner's Cough-Cold Syrup (morphin).
Jackson's Magic Balsam (chloroform and morphin).
Kohler's One-Night Cough Cure (morphin sulphate, chloroform, and cannabis indica).
Van Totta's Cough Pectoral (morphin and chloroform).

†Linseed, Licorice and Chlorodyne Cough Lozenges (chloroform and ether).
Linseed, Licorice and Chlorodyne Pastilles (morphin, chloroform and ether).
Pastiles Paneraj (morphin and codein).

nent and distressing, leading the victim to the belief that the medicine is actually bringing about the results claimed. The ravages of the disease are, however, neither checked nor abated, in spite of the fact that the patient appears to feel better. The most disastrous feature of the scheme is that the unforunate sufferer is robbed of valuable time which could be utilized to advantage in restoring his strength and health. It is well known that if treatment is begun early the disease can be arrested, but not by using these worthless and deceptive nostrums.*

Headache mixtures are advertised as cures or effective treatments for many ills of mankind, ranging from cholera morbus in infants to "brain fag" and exhaustion due to drunkenness. They have been the cause of many deaths and hundreds of cases of poisoning.

The amount of acetanilid, acetphenetidin, antipyrin, caffein, etc., used in preparations of this class of habit-forming remedies is very large. Until recently it was claimed by some that these agents were harmless and did not belong to the habit-forming group. Later investigations, however, clearly show that this position is unwarranted. The medical profession for some time fondly believed that the depressing effects of acetanilid were counteracted by caffein, which is present in most headache mixtures, but pharmacological experiments have shown that the assumption is erroneous. The caffein in these mixtures may stimulate the heart to greater activity for a short period, but the depression induced by the acetanilid is persistent and increases in proportion to the amount used. Several preparations of this class, in addition to the usual ingredients, contain codein, a drug which is replacing opium and morphin to some extent.†

One of the most pitiable and intractable diseases of mankind is epilepsy. There is no drug or mixture of drugs known to the

*Some of the well-known remedies of this class are the following: "Piso's Cure, a Remedy for Coughs and Colds," formerly known as "Piso's Cure for Consumption" (cannabis indica and chloroform); "Shiloh's Cure," formerly known as "Shiloh's Cure for Consumption," Dr. Brutus Shiloh (heroin and chloroform); "Prof. Hoff's Consumption Cure" (opium); "Yonkerman's Consumption Cure," called "Tuberculozyne" (heroin); and "Gooch's Mexican Consumption Cure" (morphin sulphate).

†Representative products of this class are: "Royal Headache Tablets," "Antikamnia and Codein Tablets," "Ammonal with Codein and Camphor," and "Sal Codeia Bell." The subject of headache mixtures has been treated extensively elsewhere. (U. S. Dept. Agr., Bureau of Chemistry Bull. 126, entitled "The Harmful Effects of Acetanilid, Antipyrin and Phenacetin," and Farmers' Bulletin 377, on the "Harmfulness of Headache Mixtures," and the only object in referring to these remedies here is that none of the important links in the drug-addiction chain may be missing. These remedies in general simply benumb or stupefy the senses, but do not remove the cause of the trouble.

medical profession which will eradicate the disease. The best that can be done for its victims is to diminish the frequency of the attacks by giving certain medicines and regulating the diet. The various mixtures on the market contain one or more of the bromides, but a number contain, in addition, morphin or opium, the primary purpose of which is to create a demand for the remedy.

There are quite a number of so-called tobacco-habit cures on the market. All of them are ineffective, and some contain cocain in one form or another. Instead of eradicating what is commonly believed to be a comparatively harmless habit, there is grave danger of fastening a pernicious drug habit upon the user.*

With the exploiting and advertising of medicines containing habit-forming agents it is but natural to expect that drug addiction would result. It is only surprising that the number of cases is not greater. The reasons for this probably are, first, that the average individual is horrified to think of becoming a drug addict; second, the secret of many of the habitués dies with them; and, third, the most common cases, i.e., those using cocain, morphin, and opium, are short-lived, most of them dying within ten years after contracting the habit. The craving for the drug, with rare exception, cannot be controlled or overcome as long as the drug is obtainable.

There are at present "mail order express treatments" for all kinds of drug addiction. All correspondence and transactions take place through the mails except the sending of the "dope" itself. It is usually represented by the exploiter that the habit can be successfully treated at home, by the particular treatment he is interested in, and its composition is a profound secret, known to him alone. As a rule, these treatments are composed of well-known drugs. In most instances they contain the very drug or drugs for which the treatment is advertised and sold. For example, one physician furnished a treatment to a supposed morphin addict, containing, according to his own statement, 22 grains

*Examples of preparations of this character recently examined and found to contain cocain and cocain derivatives are Coca Bola, Tobacco Bullets and Wonder Workers. The Coca Bola is marketed by Dr. Charles L. Mitchell, of Philadelphia, and the Tobacco Bullets by the Victor Remedy Company, now the Blackburn Remedy Company, of Dayton, Ohio, while the Wonder Workers were prompted by George S. Beck, of Springfield, Ohio.

of morphin to the fluid ounce, and in addition 4 minims of fluid extract of cannabis indica in the same amount.*

There are at present at least thirty of these treatments sold throughout the United States. They are sent indiscriminately into any home, although some of them contain sufficient poison to kill a dozen men, and in only one instance has the writer observed a statement of warning relative to their poisonous character. Some of the promoters themselves have little knowledge of the dangerous character of the mixtures they are handling. For example, it was found that one of these treatments, handled by a groceryman who had neither medical nor pharmaceutical knowl-

FIG. 101.—TYPICAL "TREATMENTS" FOR DRUG-ADDICTION.

edge, was distributed to anyone asking for it. In some instances these men organized into firms or corporations and employed doctors to assist them in their nefarious business. The chief reason for employing a physician in this connection is to evade the various State laws, because a business of this character would probably be construed as practicing medicine, and such practice is

*Another "doctor" supplied a mixture containing on the average 14.2 grains of morphin sulphate to the ounce. A package sent out by the James Sanitarium for the treatment of a supposed morphin addict contains 24 grains of morphin to the fluid ounce. A treatment of Habitina, supplied by the Delta Chemical Company, according to the label on the package contains 16 grains of morphin sulphate and 8 grains of diacetyl morphin (the chemical name for heroin, a derivative of morphin) to the fluid ounce. An interesting practice in vogue is the sending of a supply consisting of a number of bottles marked from 1 to 18 inclusive, or whatever number there may be. In one instance, for example, 10 bottles were delivered marked "first supply," numbered from 1 to 10, inclusive, and every one bore the same inscription, namely, "Dionin 2⅔ gr., morphin 4 gr. per fluid ounce." Each bottle held about 4 ounces of fluid, which means that it contained 16 grains of morphin and about 10 grains of dionin, a morphin derivative.

denied to persons not legally qualified as medical practitioners. These physicians very well understand that there are at present no substances known to the medical profession which can be used successfully in the treatment of drug addicts without the careful supervision and restraining influence of the medical man himself and the constant attendance of a nurse acquainted with drug ad-

FIG. 102.—ONE OF THE "GRADUAL REDUCTION TREATMENTS" FOR DRUG ADDICTION

diction cases. It is well known that the drug addict is incapable of treating himself. The chief object of this practice seems to be to extract money from the unfortunate victims, who in many instances continue the treatment over a period of years.

In other instances the gradual reduction treatment is resorted to, but the reduction is very gradual, being in some instances at the outset 1 grain per month, when as much as 12 grains were used at the time the treatment was begun. In other cases no at-

tention is paid to the progress of the patient, and if a second or third supply is ordered it is sent without question as long as the price is paid. This feature was clearly demonstrated by ordering from various institutions and individuals their various treatments; after a lapse of time, without giving any information as to the progress of the case, the second treatment was shipped without question or inquiry as to the patient's condition. Furthermore, in some instances the amount of opium or morphin present in the second supply is even greater than that present in the first.

Another very interesting feature brought out in connection with this business is the fact that the demand for the treatments is greater in States having stringent anti-narcotic laws; for example, the laws of Texas or California or of the District of Columbia, Virginia, etc., relative to the sale or disposition of opium, cocain, and morphin, or preparations containing the same, are rather stringent and rigorously enforced, with the result that the demand for these drug treatments is greater in these jurisdictions than in certain other sections of the United States. In some instances even physicians evolve and operate the schemes. Some State laws contain a clause making it illegal for a physician to prescribe indiscriminately to habitués, but in cases of the character under consideration, where most of the material is shipped out of the State, little attention is paid to the business by the local authorities. It is obvious that unscrupulous physicians are the prime transgressors in fostering the perpetuation of these fraudulent so-called drug-habit cures.

There are various remedies on the market used from infancy to old age containing habit-forming agents which can be purchased almost *ad libitum* by anyone. Many of the mixtures are concocted, directly or indirectly, through the aid of unscrupulous physicians, so called. Some illicit sales of cocain, morphin, etc., are also made by druggists, both wholesale and retail. A few physicians take advantage of the authority intrusted to them for the proper using of these habit-forming agents and prescribe for all requesting them, regardless of the health and welfare of the public. Physicians often are not circumspect enough in the writing and safeguarding of prescriptions containing these drugs. With these conditions obtaining, drug addiction has become a great evil, and the question naturally arises, how can it be mini-

mized or eradicated? There is a great diversity of opinion on this point, but the following are the lines along which results can be expected:—

First: Educate the public through the press and by pamphlets, lectures, etc.

Second: Enact laws forbidding the sale of all pernicious habit-forming drugs, such as cocain, morphin, opium, heroin, etc., and their derivations and preparations, at retail, except on prescriptions of physicians, dentists, or veterinarians.

Third: Require a permanent record to be kept, subject to State and federal inspection at all times, of all transactions in such drugs, whether wholesale, retail, or through the use of prescriptions.

Fourth: Enact laws forbidding the handling of any of these products except by manufacturers, wholesale and retail druggists, and others legally qualified.

Fifth: The State boards of health, or other governing bodies, should be empowered to withdraw the licenses of physicians who prescribe or druggists who sell these articles for other than legitimate medicinal purposes.

Sixth: A federal law should be enacted forbidding the shipment in interstate commerce of habit-forming drugs or preparations containing them, except through the customary channels of trade, and then only when complete records of all transactions are kept.

CHAPTER XII

Streets and Their Construction.

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In dealing with the subject of streets and their construction, I shall not confine myself to a discussion of purely municipal problems, but will construe the word "street" as being in its purer sense derived from the root "stratum" or "strewed away." For do we not read that in the fifth year after the Roman conquest of Britain there were four great streets which crossed the island, of which two ran lengthways and two crossed it?*

The art of road building is undoubtedly of great antiquity, and it requires but little flight of the imagination to suppose that even paleolithic man, who learned how to chip out weapons of stone, had also learned to pass more conveniently over bog and slime by the use of the same material. Coming down, however, to the safer ground of history, we find records of the art of road building which excite our wonder and even tax our credulity. Herodotus tells us of the great Egyptian road on which King Cheops, about 4,000 years before the birth of Christ, employed 100,000 men for many years, and to the east of the great pyramid there still remain the vestiges of this great stone causeway. This road was constructed, we are told, though we may well doubt it, of massive stone blocks ten feet in thickness, and over it was transported the materials of construction for the great pyramids. Strabo tells us that the streets of Babylon were paved about 2000 B. C., and that great constructed thoroughfares connected that center of civilization with the important cities of Memphis, Susa, Ecbatana and Sardis. Again, Herodotus is our authority for the fact that not only stone but natural bitumen or asphalt was used as a material of construction nearly 2,000 years before Christ.

*"Watlinge Strete, Fosse, Hilkenilde Strete and Erminge Strete."—Guest, "Origines Celticae", II., 218.

Prescott, in describing the extraordinary prehistoric civilization of the Incas, the ancient inhabitants of Peru, reminds us that the traveller still meets with memorials of the past, remains of temples, palaces, fortresses, terraced mountains, great military roads, antiquities and other public works which astonish him by their number, the massive character of the materials and the grandeur of design. Most curious of all are Prescott's and von Humboldt's descriptions of the character of construction represented in the wonderful system of highways builded

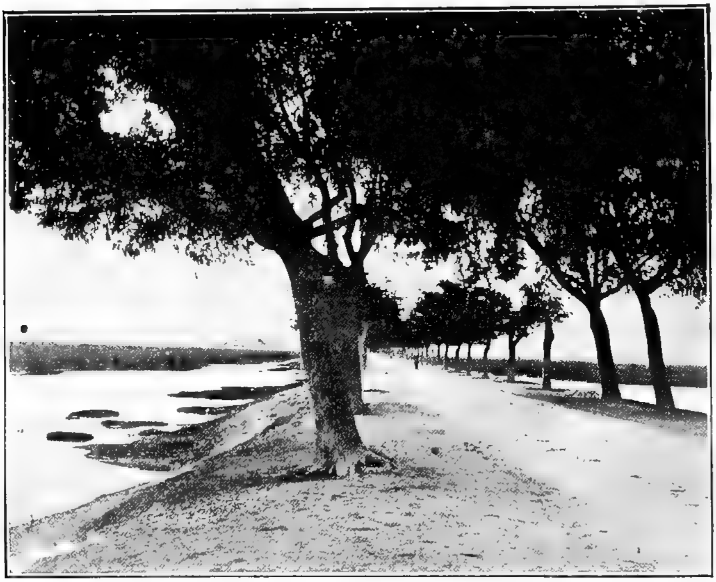

FIG. 103.—PYRAMID ROAD.

by the Incas. They were, it seems, for the main part built of heavy flags of freestone, and in some parts at least covered with a bituminous cement which Prescott tells us time has made harder than the stone itself. Prescott further relates that a certain Spanish priest known as Father Velasco, who played a part in the conquest of Peru, is in raptures with "an almost imperceptible kind of cement" made of lime and bituminous substance resembling glue, which was incorporated with the stones so as to hold them firmly together like one solid mass,

yet left nothing visible to the eye of the common observer. This glutinous composition mixed with pebbles made a sort of macadamized road much used by the Incas, as hard and almost as smooth as marble.

When we consider that the civilization of the Incas reached its highest development, as shown by the remains of their buildings, fully four hundred years before their discovery by the early Spanish invaders, we are indeed left to wonder at the way history repeats itself, for it is only of comparatively late years that our own civilization adopted the use of bitumens as binders in road construction.

FIG. 104.—THE APPIAN WAY, NEAR ROME.

The ancient Romans are said to have learned the art of making paved roads from the Carthaginians, and about 300 years before Christ the construction of the great military highways of the empire was at its greatest hight. The celebrated and well-known Appian Way was commenced by Appius Claudius while holding the office of censor in 312 B. C. In the construction of this as well as the other great military highways the Romans adopted a system of engineering which could not at the present time be used or even remotely imitated. Composed of at least four layers of largely solid masonry glued together by

lime cements, these roadways have withstood all the ravages of time. Besides the main military highways built upon these solid foundations, the Romans had also learned a cheaper form of construction for outlying roads, which were treated or strewn with gravel and stone detritus. A French scholar named Nicholas Bergier, writing in 1728, on the history of the great roads of the

FIG. 105.—THE APPIAN WAY. OLD FRENCH ALLEGORICAL ENGRAVING SHOWING CONSTRUCTION IN PROGRESS.

Roman Empire, shows conclusively that many practices were in vogue among these ancient peoples that we have always been inclined to believe discoveries of our own times. This author, for instance, gives us an account of the use in road building of the puzzolan cements made from the Vesuvian lavas. But perhaps most curious of all is the statement based upon the

authority of contemporary historians that in order to render this species of paving stronger and more resistent, they were, in some cases, mingled and covered with a certain varnish, which was described as rendering the roadways resistent to all the injuries of time, and this varnish was composed of lime tempered and mingled with linseed oil. In view of the fact that this and similar methods of mingling various types of oils with cement have been made the subject of research in the laboratories of the

FIG. 106.

office which I represent, the reference to the ancient use of binders of this nature becomes a matter of great interest. The words of the contemporary writer quoted by Bergier are as follows:

"Et crustis istiusmodi constat si lotura calcis aspergantur, si oleo linaceo oblinantur, importari duritiem quamdam vitream, et contra tempestates illaesam."

Once more we are led to reflect that there is indeed nothing new under the sun.

With this brief review of the ancient contributions to the art and science of road building, we may pass rapidly over the

intervening years of the dark ages to the beginning of what may be called the modern era. This properly begins with the French systems as commenced by the great Napoleon and afterwards inculcated and laid down by Tresaguet in 1775.

With Tresaguet begins the era of broken stone road construction which was afterwards developed by the famous Scotchmen, Macadam and Telford. The contributions of these two eminent engineers may be said to have builded for their names imperishable monuments in broken stone. The more recent experiences of highway engineers who have to study the relation of the road

THOMAS TELFORD.

FIG. 107.

to modern traffic conditions would, however, appear to show that the macadam type of road is more perishable than the name that it perpetuates. An eminent authority on road building, Mr. Austin B. Fletcher, has recently said:

"Macadam's road is a thing of the past. In fact, a road of the kind built by the Scotchman and named in his honor, has been obsolete in this country for so long a time that the roadmakers of the present day have almost forgotten what it was

like. Except that it was made of fairly small broken stones, it bore little resemblance to the carefully built broken stone road adopted for State highway constructions of the present day. Macadam knew nothing of machine-broken stone, and he did not dream that a broken stone roadway could be made as smooth as a billiard table immediately on its completion, by the use of steam road rollers, and it is probable that his roads, even if the traffic had consolidated them, would not be smooth enough to please our motoring friends when operating at their usual speeds. Macadam methods of construction would be considered wasteful to the extreme, considering the present day prices of labor."

But now it appears that even the carefully built broken stone roads of the present day that Mr. Fletcher speaks of are no longer suited to withstand the intensive traffic represented by the combination of horse-drawn and motor-driven vehicles. A few figures may be of interest which bear upon the growing intensity of modern traffic conditions. The Massachusetts Highway Commission has recently completed a census of the summer and autumn travel on the roads under its jurisdiction, taken from about 240 different stations. It appears that about 42 per cent. of the traffic last summer on the State roads of Massachusetts was self-propelled. It is estimated that at the present time there are nearly 40,000 automobiles using the roads of the United States, and that the manufacturers of the country are busy supplying the demand for these vehicles at the rate of from 10,000 to 12,000 machines per month. Now, let us see what effect this growing use of the automobile has had upon the horse. In 1896, when the automobile era began, the census statistics show that there were in the country about 16 million horses, whose average value was about $33 per head. In 1909, in spite of the growing use of automobiles, the number of horses had increased to nearly 21 million, and the average value had increased to about $95. From the same source we learn that in 1896 there were nearly 3 million mules in the country, while in 1909 these had increased to over 4 million, and at the same time the average value of these animals had increased from $45 to $108.

The growing use of self-propelled vehicles has made it ap-

parent that even the best form of ordinary macadam construction is unfitted to stand the disruptive action of rapidly moving rubber-tired wheels. It is from this point on that the engineer has been obliged to turn to the chemist for information which will aid him in devising new forms of road building and new methods of treating the surfaces of roads already constructed. Some 12 or 15 years ago there came a rumor out of the far West that in California the ordinary earth and shale roads were being treated with oil, and that the results obtained were satisfactory.

FIG. 108.—SPREADING TAR BY HAND, WESTWOOD, MASS.

Gradually the impression became prevalent that a universal panacea for bad and dusty roads had been found. In many places oil was purchased and scattered on the roads with direful effects. Following these failures there grew up in certain localities a very natural prejudice against the oiling of roads, and, since to the average layman every treated road is an oiled road, this prejudice included every sort of bituminous product which was proposed. Then followed, first in England and France and afterward in Germany and the United States, experiments with the use of tars as paint coats to be applied to the surface of old macadam roads. It was at this point that the chemist may be said to have first joined hands with the engineer as a road builder. Through

the co-operation of the chemist it was soon found that there is a wide difference in both tars and natural oils in their suitability for road treatment. Oils, even from the same field, vary in the quality of the base or residue which is left after the lighter constituents are evaporated. In addition to this, the practice in the United States of transporting oil in pipe lines leads to unknown mixtures, and an uncertain character or quality of oil, however it

FIG. 109.—SHOWING DUST RAISED BY AUTOMOBILE ON MACADAM ROADS.

may be graded or whatever it may be called. Some oils yield a high percentage of so-called asphaltic base while others leave residues which partake of the nature of paraffin or vaseline. It would seem that the oils of the former nature would be the only ones that should be used for road purposes, but even these differ so widely from each other and so little is actually known at the present time in regard to the subject, that the problem of framing entirely satisfactory specifications for all kinds of road oils is taxing the best efforts of engineers and chemists who have been making a special study of this subject.

Tars also and other products are not standard substances, and some of them are undoubtedly quite unfit for road building. High temperature coal tars, made by modern methods of gas manufacture, are to some extent cracked or burned. The percentage of free carbon in such tars is usually high and it is believed by some engineers that this is a disadvantage and should be covered by specifications. On the other hand, other engineers and chemists believe that reasonable amounts of free carbon, even up to 20 per cent., are not injurious, and they point out that

FIG. 110.—PRAED-AITKEN TAR SPREADER IN OPERATION.

this free carbon may act a part of a filler in the use of the material.

Tars also vary in their nature in accordance with their source, so that a by-product coke oven will yield a tar which differs to a considerable extent from a modern gas-house tar. In many cities of the United States water gas is used to enrich or mix with coal gas. Water gas, which is known to the chemist as a mixture of hydrogen and carbon monoxide, is made by passing steam through a glowing bed of coke or anthracite coal. This gas burns with a pale bluish flame and in order to give it illuminating properties it is enriched with hydrocarbon oils, usually petroleum distillates. Water gas tar, which is obtained as a by-

product of this process, is very different in its nature from coal tars. The varying processes of refining are also often responsible for the great differences which are found to exist in the properties of the various bituminous products which are now being presented to the road builder. Before they can be satisfactorily employed as road materials it is necessary that most of the crude oils and tars be refined. This is usually accomplished by distilling them in large cylindrical iron stills, the operation being quite similar for both kinds of material. In the distillation process two general classes of products are formed which are known as distillates and residues. The former are almost invariably thin, oily liquids of little or no use for road treatment, as they possess no binding value. Residues, on the other hand, are of considerable value for this purpose, providing a suitable material is distilled in the proper manner.

When moderate temperatures are employed during distillation, a mechanical separation of the constituents or fractions of the oil or tar is effected and the process is said to be a purely fractional distillation. In such cases the distillates consist only of the more volatile portions of the original material while the residue represents a concentration of the binding base, if this was originally present. By controlling the amount of distillate removed, it is possible to obtain a residue of any desired consistency greater than that of the crude product, from liquid to solid. The fluid residues are of value in the surface treatment of roads and should be applied cold or hot, according to their viscosity at ordinary temperatures. The semi-solid and solid residues are mainly of value in the construction of bituminous bound roads.

Any inert, non-volatile material, such as free carbon, which was present in the original bitumen, will necessarily be found in greater proportion in the residue obtained by distillation, and this fact has to be considered with regard to the possibility of producing a suitable road binder from any given raw material.

If excessively high temperatures are employed during distillation, certain of the hydrocarbon molecules are broken off or cracked into two or more compounds, one of which is considerably richer in carbon than the original; and if these reactions are pushed to their ultimate conclusion, free carbon is deposited in the residue as coke and the process is said to be a destructive dis-

tillation. Badly cracked residues are of inferior quality for road purposes and their use should be avoided.

If in the preparation of a residue it is desired to remove certain constituents which under normal conditions would be cracked before their boiling point is reached, recourse is had to distillation *in vacuo* or to the use of a jet of steam. In the first method the boiling points of the oils which are to be removed are lowered to a point below the cracking temperature, and in the latter these oils are to a certain extent mechanically dragged over into the distillate by the excess of steam at a temperature below their cracking point.

In certain cases where it is desired to thicken or increase the consistency of a fluid residuum, air is blown through the hot residuum. This results in the formation of certain oxidized products and also in the formation of hydrocarbons known as nucleus condensation products. The latter class of compounds are produced by the removal of one or more hydrogen atoms from two hydrocarbon molecules with the formation of water and the joining together of the molecules which have been deprived of hydrogen.

The consistency of blown products is largely dependent upon the extent to which the material has been blown. Providing the operation is not carried too far, blown tars and oils possess certain desirable properties which may not be found in the ordinary residues. Thus the susceptibility of the bitumen to temperature changes is usually decreased by this means, but, on the other hand, its adhesiveness may also be lessened to some extent.

In the study of these problems the chemist is now co-operating with the highway engineer and the inclusion of this topic in a course of lectures on municipal chemistry is, therefore, both appropriate and timely.

For the construction of city pavements experience has taught that up to the present time only four or five classes of material need be seriously considered. These are stone in the form of blocks or cobbles, asphalt, wood block, or brick, all of which are or should be laid on a concrete foundation, and, lastly, concrete itself. The type of pavement best suited to urban conditions must, of course, depend to a large extent upon climate and the intensity of traffic. In the selection of material for city pave-

ments many important questions have to be considered, among which we may enumerate noiselessness, slipperiness and general appearance. In the long run, however, other things being equal, economy, which includes at the same time the original cost and average length of service under given conditions, should be an important factor.

The wood block, well sanded or gravelled in wet weather, has found favor in many of the great cities of Europe, more especially in London. In most of the cities of this country the modern asphalt pavement appears to be preferred. According to Tilsen, in 1900 seven principal cities of the United States, excepting Chicago, had 850 miles of asphalt pavement against 13 miles of wood block. Chicago, however, had 763 miles of wood block as against 79 miles of asphalt. During the last 10 years great changes have been made, and though asphalt still holds the predominant place in most big cities, the use of wood block, brick and special types of bituminous macadam has been much extended.

Country Roads.—After these brief general remarks on city pavements, in which it may be noticed the drawing of definite conclusions has not been attempted, I may perhaps be permitted to seek the purer and more salubrious air of the country. There are something over 2,000,000 miles of public highways in the United States outside the corporate limits of the cities, and it is with the up-building and up-keeping of these rural highways that we are now mainly concerned.

The relation between the public road and the public good is closer than is generally realized by those who have not made a special study of the subject. Although it is my present object to set forth some of the modern technical aspects of the road problem, I may perhaps be allowed to digress for a moment. Education, agriculture, commerce and labor are all deeply dependent upon the means and modes of transportation which inevitably begin upon the public road. On one of the great public libraries of our country is printed the legend: "The Commonwealth demands the education of the people as the safeguard of order and liberty." This is a splendid sentence, but in the Commonwealth of our States there are those in which the impassability of the roads during a considerable portion of

the year prevents attendance at church and school. To cite one instance taken from statistics compiled by the twelfth census, one State with less than 2,000,000 inhabitants contains more than 175,000 native white adults born of native parents who can neither read nor write. To decide whether bad roads and public shiftlessness are due to lack of education, or *vice versa,* is like trying to divorce the horse from the cart, but undoubtedly statistics point directly to the fact that road improvement and extension of education move forward hand in hand.

FIG. 111.—COUNTRY SCHOOL HOUSE ON GOOD ROAD NEAR KNOXVILLE, TENN.

If we turn to agriculture we may well inquire to what extent the high cost of living may be affected by the condition of public roads. It has been computed from carefully gathered statistical information that if our corn crop of 1905-6, which marketed 40,000,000,000 pounds of corn, was moved in wagons holding about 2600 pounds each, an average haul of seven miles to the railroad or market place, then that crop was hauled more than 100,000,000 miles on the public roads.

Leaving the question of the bearing of bad roads upon the

commercial and educational development of our country, I may take up the subject from the standpoint which will particularly appeal to a modern audience. The public roads of a Commonwealth are legitimately intended to be used for pleasure, for the development of social intercourse, for the broadening effects of travel and intimate knowledge of our own country, and for enabling us to pursue the beautiful and picturesque in nature. The automobile, without any doubt, has done more to develop the usefulness of the common roads from this point of view than all other influences combined. Unquestionably the automobile has brought up new problems to be confronted by the road builder and engineer. The systems of construction of stone roads developed by the great engineers whose names will ever live in the history of engineering, Tresaguet, Telford and Macadam, were not designed to carry the heavy shearing traction of self-propelled vehicles. To this shearing force developed by the driving wheels of the mechanically impelled vehicles are due the rapid disintegrating effects which have become a matter of common observation wherever automobiles are used to a large extent. You are undoubtedly aware that following this observation a hue and cry has been raised throughout the length of the land condemning the automobile and agitating for legislation which will have the effect either to some degree of preventing the use of these vehicles or by some method of taxation making the automobilists responsible for the expenditures which fall upon the public treasury to maintain the roads in good condition. Fair-minded students of this condition have, however, concluded that, though the automobile is to a certain extent a road destroyer, it is at the same time doing more than any other influence to bring about a correction of the evils which have followed in its wake. Engineers all over the world are turning their attention to methods of construction which will meet the modern condition, and that successful results have already been obtained and are constantly being pushed further, I need not remind you.

The dust problem did not begin with the introduction of the automobile, although it has undoubtedly been accentuated by this mode of travel. There are sections of our country at this present time where the roads have been rendered practically

dustless, and neither horse-drawn vehicles nor automobiles can now deposit the dirt of the highways in the gardens and houses of abutting property owners. This condition of affairs did not exist before the introduction of the automobile, but has been arrived at in answer to the demand which has followed its use. In short, there are many suburban communities in which life to-day is far more agreeable, pleasurable and possible than it was before automobiles came into use. That dust is a disease carrier there can be do doubt, and it is necessary that we should expend all of our energies towards its suppression. It should be remembered that the automobilist is not a dust maker, but he is a dust raiser, and therefore it is especially incumbent upon him that he should co-operate in every possible way, bringing all his influence to bear to encourage the suppression of this dangerous nuisance.

CHAPTER XIII.

Modern Road Construction.

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The inclusion of the topic of Modern Road Construction in this course of lectures on Municipal Chemistry may appear to require some justification. This is, however, not far to seek. One of the very many great civic problems of modern times is the dust nuisance. In a paper presented to the American Civic Association, the writer said:

The dust nuisance, like most of the problems of modern time, must be considered as having a double aspect. There is always the point of view of the producer, as well as that of the consumer, to be considered. In the dust problem, however, the consumer does not demand the product, and the producer does not desire to provide it. The problem is further complicated by the fact that, to a very large extent, the producer is also the consumer. There are 2,151,270 miles of public roads in the United States proper, outside of all municipalities, and these may be fairly considered to constitute at least one of the great National dust factories. It is always entertaining to juggle with figures, and while it may be admitted that this is often a dangerous practice, it sometimes enables one, by adopting a factor of safety, to conservatively emphasize the magnitude of the existing evil, and thus arouse the civic sense to the necessity of its suppression. Allow me, therefore, with this object in view, to indulge in a somewhat arbitrary juggling of statistical information, which I will endeavor to make err on the safe side of the argument.

That a vehicle moving rapidly along one of our highways in dry weather raises into the air, and is followed by, a cloud of dust, I need not remind you. Provided that there is at the same

time a draft of air moving, and there generally is, this material will leave the roadway and settle upon the surrounding country and objects. If we assume that each cubic yard of this dust cloud which follows the moving vehicle would be found to contain one-half an ounce of material, were we able to collect and weigh it, and this is certainly a conservative estimate, it would appear that in traversing a distance of one mile on the public road a single vehicle would have removed 880 ounces, or 55

FIG. 112.—SHOWING DRIFT OF DUST TO ROADSIDE.

pounds of dust. Ten such vehicles following each other over the same mile would remove, therefore, about 550 pounds to the mile. As there are few miles of the public roads in the United States, if we take them on the average, over which ten vehicles do not pass in the course of one day, we can see at once that, at a conservative estimate, the public roads of the United States are losing certainly as much as 1,000,000,000 pounds of material every dry day in the year. A billion pounds of material are equal to 500,000 tons.

If we assume that there are 100 dry days in the year, we may well ask ourselves what is the economic bearing upon

our national and civic life of the annual movement, from places where it is needed to places where it is highly undesirable, of 50,000,000 tons of material. If all the 2,000,000 miles of public roads were macadamized, the construction engineer could soon calculate the cost in money, as he knows only too well that this same dust, in the form of stone or screenings, rarely costs him less than $2 per ton on the road. What shall we say, however, of the effect of these moving dust clouds upon the public health, of the public discomfort, of the beauty-destroying effects?

When all the traffic which passed over macadam roads was steel tired and steel shod, a sufficient amount of dust was continually worn off from the stone aggregate to supply that which was lost from the road owing to natural agencies, such as wind and rain. Those who have studied the art of road construction know that the fine dust acts the part of a binder upon the coarser stones which make up the main body of a macadamized road. As soon as the dust is removed by any agency whatsoever, the coarser stones loosen and the road soon ravels to pieces. Under a grinding traffic, therefore, it is apparent that, although a certain amount of dust is being lifted and removed from the road, more dust is continually being worn off to take its place. With the advent of pneumatic rubber-tired vehicles a new condition arose. These soft inflated tires grind no dust from the stones to replace that which is removed by the agencies already spoken of.

It has been very generally believed that the pneumatic tires on motor driven vehicles actually suck the dust from between the coarser stones due to the action of a partial vacuum, which is supposed to be due to the continual deflation and inflation of the rubber at the bearing point of the tire. Although it is probable that this action does take place to a slight extent, it is not the main cause of the rapid destruction of macadam road surfaces by automobiles. Automobiles differ from animal-drawn vehicles in the fact that they have a very high tractive force, which exerts a continual shearing upon the bonded surface. The Office of Public Roads has made a special study of this subject, and has conducted a series of tests. The inspection of instantaneous photographs made of rapidly moving, high-power cars passing

over macadam surfaces invariably shows that the great damage is being done, not by the front wheels, but by the rear wheels alone, upon which the tractive force is exerted. In whatever way the damage is done, however, there can be no doubt but that highway engineers are confronted with a new and very serious problem in maintaining macadam road surfaces. Various measures are being adopted, as yet, however, mainly in an experimental way, to overcome this difficulty. About a year ago there sat at Paris an International Road Congress called under

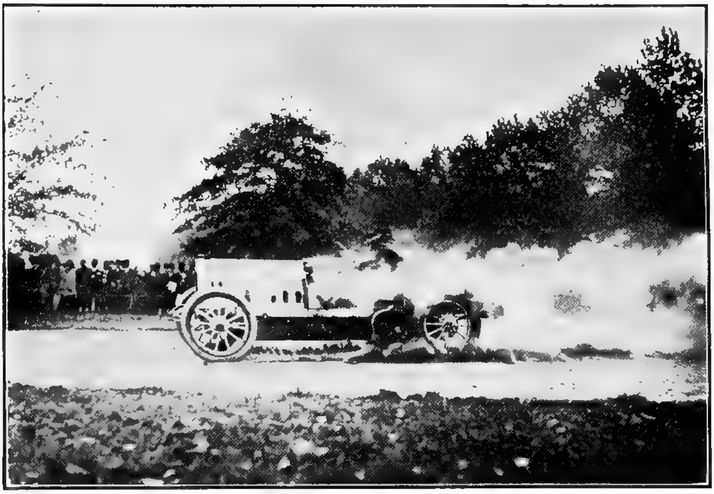

FIG. 113.—AUTOMOBILE GOING 80 MILES AN HOUR, SHOWING SHEARING EFFECT ON ROAD SURFACE.

the auspices of the French Government for the particular purpose of studying this problem and collating the information of highway engineers from all civilized countries, and this coming summer* another session of the Congress will meet in Brussels to carry on and perpetuate this work. All this shows how important the problem appears to the older European countries.

The suppression of dust is not, however, the principal object of these deliberations. Far more important is the question of the life of the road, for the money value involved in construction must necessarily overbalance every other aspect of the problem.

*1910.

England is said to expend about $80,000,000 annually on about 150,000 miles of public road, while the United States expends and largely wastes about the same sum on her 2,000,000 miles. The principal difficulty experienced by the modern highway engineer lies in the fact that he is called upon to devise ways and means for constructing and maintaining road surfaces which will withstand a combined horse-drawn and motor-driven traffic. The old and well-tried system of macadam construction had proved itself to be adequate to horse-drawn traffic, but with the advent of the automobile a new problem appeared, and it has become increasingly evident that entirely new forms of road construction and treatment must hereafter be adopted. This end may be sought by new construction or by penetration methods, which consist in applying bituminous or other liquid or semi-liquid substances to old macadam or other road surfaces. The use of various by-products of manufacture for road material is particularly interesting in view of the fact that by such adaptation of waste substances we not only conserve material, but we may lengthen the life and add to the attractiveness of the road.

Moreover, from our present point of view this phase of the subject will be of special interest, because for the first time it introduces the chemist as an important factor to the success of modern road construction. Among the by-products which have been to a considerable extent used or experimented with we may mention oil residuums and tars, crude or refined, furnace slags, concentrated waste sulphite liquors from the paper mills, calcic chloride from the caustic alkali manufactories, and waste molasses or black straps from the sugar refineries. We have already in the preceding chapter considered some of the properties of bituminous substances, such as oils and tars, which particularly adapt them for road building. Probably the best method of using materials of this nature is in the original construction of the road. Broken stone or sometimes slag is coated with a properly selected, hot bituminous substance and rolled down on a prepared subgrade or base. It is not my intention to discuss the various specifications that have been drawn by engineers for carrying out work of this kind. As a matter of fact, the subject is complicated in this country by the fact that certain patents have been granted which appear to be construed by the holders, as

well as to some extent by the Court, as covering very generally the field of bituminous macadam, provided the mineral aggregate is so mingled as to reduce the percentage of voids to a rational minimum, thereby obtaining the highest degree of stability in the road. In some cases, however, where mingled stone aggregate is not used, or where evenly screened stone is coated with the bituminous cement and rolled down in layers, very excellent results have been obtained. The opinions of highway engineers vary widely as to the best specifications for use in bituminous macadam construction, and as this is a problem for the engineer rather than the chemist, I shall take no time for its further discussion. The penetration methods have been largely used in Europe and to a lesser extent in the United States, and have led to some very excellent results, as well as to a considerable number of serious failures.

Probably the penetration method which is most used in this country consists simply in sweeping the surface of old macadam roads in dry weather and then applying the bitumen either hot or cold as a sort of paint coating, allowing the road surface to absorb as much of the material as it can. The excess of bitumen on the surface is then sprinkled with rock screenings, sand or sweepings, and the road opened to traffic. When the macadam road has been recently finished or resurfaced and the bitumen properly selected, some very excellent results have been obtained by this crude method. On old macadam surfaces which have been thoroughly consolidated, very little penetration is obtained, and the bituminous covering is apt to lift and peel in a comparatively short time. In Europe and to a less extent in this country special tank wagons have been devised in which the hot bitumen is sprayed or atomized under pressure on to the swept road surface, thus expediting the work and obtaining far better penetration. The quality and specifications of the bitumen for work of this nature have to be very carefully considered, and in this work it is absolutely necessary for the engineer to have the co-operation of a chemist experienced in the examination of bituminous materials. The bitumen must have a base or residue which has a high binding or cementing value, as the application of oily material of a purely greasy nature may lead to

expensive and disagreeable failure. If it were possible to state definitely in a few words the specifications which a material should have in order to insure successful results, they would be included here, but this is not possible. The effect of climate, the nature of the road and the kind of stone, gravel or soil of which it mainly consists, are all important factors which have to be taken into consideration. In addition to this, the subject has only recently been a matter of investigation and study by highway engineers and chemists, and is therefore at the present time in a somewhat chaotic condition in which very considerable differences of opinion exist even among the most expert workers in the field. This has already been to some extent shown in the preceding chapter. One State specification, for instance, calls for not less than 10 per cent. of free carbon in a road tar, while another will not allow more than 17, and still another specifies not less than 12 or more than 21 per cent. Special committees of the American Society for Testing Materials and the American Society of Civil Engineers are now studying these questions, and it is hoped that order will shortly be brought out of chaos.

Somewhat more than 20,000,000 tons of furnace slags are produced annually in this country, but up to the present time they have not been very generally used as road material. A special study of this subject has been made in the laboratories of the Office of Public Roads in Washington. From these investigations it appears that slags can be divided into distinct classes as far as their value for road building is concerned. It appears that as a rule the basicity of a slag affects its stability under the action of water, and therefore the more acid slags do not bind, but gradually powder up to dust. This is in accord with previous work done on rock powders, in which it was shown that the binding power of siliceous rocks could be increased by the use, in conjunction with them, of basic rocks such as limestone and dolomite. We may arbitrarily define acid slags as those which contain more than 40 per cent. of silica, intermediate with from 30 to 40 per cent. silica, and basic slags with less than 30 per cent. In a general way it may be stated that the acid and intermediate types include the by-products of

the blast furnace and smelter, while the basic slags are derived chiefly from the basic open-hearth furnaces. Just as in the case of rocks, the binding power of the more acid types can be improved by suitable mingling with basic material such as limestone. If some form of bituminous slag macadam is to be constructed, the natural binding power of the material under the action of water is not a factor, and as a matter of fact may even prove a disadvantage. In England very excellent roads have been built by coating crushed and screened slag with a suitable bitumen, such as refined coal-tar pitch, and rolling the mixture down on a prepared subgrade.

FIG. 114.—SLAG ROAD NEAR YOUNGSTOWN, OHIO.

Another promising line of investigation for the chemical engineer who is interested in road building problems is the possible use of waste liquors from paper pulp mills as a road material.* In 1907 about 4,000,000 cords of wood or 2,000,000,000 board feet, valued at $30,000,000, were converted into paper pulp in 88 pulp mills of the United States and Canada. One-half of this wood is wasted in the sulphite liquors, which are in great measure thrown into the streams and rivers, polluting the waters and killing the fish. According to a statement in the annual address of the retiring president of the American Chemical Society, in three months one of the great New York daily news-

*The first suggestion in regard to the possible use of these liquors as road material was made to the writer by Mr. J. S. Robeson, of Au Sable Forks, N. Y.

papers will consume a forest as large as Central Park, 843 acres, while a single one of its Sunday issues would require 15 acres of forest. The sulphite waste liquors as at present thrown away have a specific gravity of about 3° to 5° Beaumé. When concentrated to 15° to 30° Beaumé these liquids have an exceedingly high binding power. Experiments carried out in the laboratory appear to indicate that they act as binders on rock dusts not only on account of their glutinous nature, but also because they induce the hydrolytic reactions on which the cementing value of a rock dust depends. This observation is in line with Acheson's process for strengthening the bond of clays by infusions of straw or tannic acid. The difficulty, however, with the use of these liquors as road binders is to some extent similar to that encountered with molasses. The bond is not entirely unacted on by water, and disintegration of the bonded surface may be anticipated. It may therefore be necessary to emulsify these binders with petroleum oils. All these problems mean work for the chemist in co-operation with the engineer. If these wastes are made available as road materials, a threefold benefit will result. River pollution with its attendant evils will to a large extent cease, the now wasted portion of the wood will be made useful, and the roads will be improved.

Calcic chloride, which is a by-product in the manufacture of caustic alkali, has been to some extent used as a dust layer, and therefore as a road preservative. The incorporation of a hygroscopic substance with the surface of a road will naturally keep it to some extent damp, and traffic does not, therefore, raise and disperse the material so rapidly over the surrounding country. Materials of this nature have the advantage of being very easily applied, as they are always readily soluble in water and can be sprinkled on the road wherever watering carts are available. For that portion of the road surfaces where sprinkling carts are not to be had, the manufacturers are now putting on the market the granulated form of calcic chloride which looks very much like popcorn. This material is scattered or sown on the road by hand or from spreaders, and very soon takes up moisture from the air and incorporates itself with the road surface. As dust layers these materials are undoubtedly efficient, but the work is required to be repeated from time to time, as

rain water will naturally remove the soluble salts, so that the road will eventually dry out and become dusty. It will readily

FIG. 115.—ROAD RECENTLY TREATED WITH CONCENTRATED WASTE SULPHITE LIQUOR IN AGRICULTURAL DEPARTMENT GROUNDS, WASHINGTON, D. C.

be seen that such a method as this should be classed as a palliative rather than a remedy for dust prevention or as a means of ultimate road preservation.

In the neighborhood of the great sugar refineries of the country, both in the cane and the beet-sugar areas, there is a considerable quantity of a by-product known as "black-straps," which contains a certain amount of uncrystallizable sugars and the resinous extractive matters from the plants. When mixed with lime, these materials form calcium sucrates and resinates which are well known to have high binding power. They are not, however, perfectly insoluble in water and are therefore gradually disintegrated under the action of moisture. In order to overcome this tendency towards disintegration, the Office of Public Roads has carried on experiments in which the waste molasses was mixed with lime and an asphaltic or semi-asphaltic oil residuum. The whole mass emulsifies readily and can be coated hot on to broken stone or other road material and rolled down on a properly prepared subgrade. About two years ago an experimental road of this nature was laid on rather a steep grade on Prospect Street in Newton, Mass., and having been through two winters and sustained a considerable amount of traffic, is now reported as being in good condition and as having given complete satisfaction. The binder was prepared in a large mortar box by first slaking 320 pounds of quicklime with 108 gallons of water. As soon as the lime was completely slaked, 92 gallons of molasses were added and thoroughly mixed, after which 50 gallons of the semi-asphaltic oil were stirred in. While the preparation was still hot it was mixed with the graded, crushed stone in the same manner as is used for coating with ordinary bituminous mixtures. Eighteen gallons were applied to every 1,310 pounds of stone, and the concrete thus produced was hauled to the road and laid as soon after mixing as possible. When rolled it produced a firm and resilient surface, upon which heavily loaded teams left no wheel marks one-half hour after it was laid. Under the action of the roller a small portion of the oil came to the surface, so that a light application of stone chips was required to put the surface in first-class shape. The idea of using molasses as a road binder usually excites derision, and undoubtedly the chief difficulty with this form of construction will naturally be the expense, and for this reason it can only be considered as practical in the immediate neighborhood

of sugar refineries, where the waste material can be obtained for a reasonable figure.

In this brief review of the use of by-products as road materials, it has been shown that from a small beginning the work of the chemist in modern road construction has grown and will continue to grow to be a matter of great importance to every civilized community. In our own work our young civil engineers, who are being trained in modern methods of road construction, are given a thorough course in the chemical laboratory to the end that they may not only become thoroughly posted on the nature of road-binding materials, but that they may also act in the capacity of analysts and investigators as occasion arises.

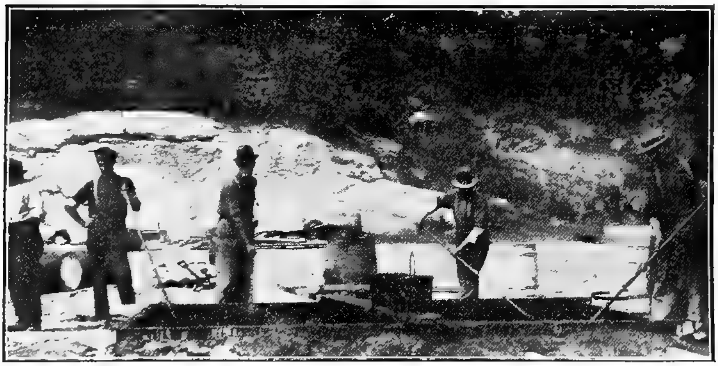

FIG. 116.—MIXING MATERIAL FOR "CANDY" ROAD, UTILIZING REFUSE FROM SUGAR REFINERIES.

In concluding these lectures I desire to take the opportunity to emphasize the fact that American roads are suffering more than the roads of other countries, not because the original methods of construction are in any sense inferior to those used abroad, but because it has not been the custom in this country, up to the present time, to devise any systematic method of maintaining the roads which we construct. The French patrol system, under which the public roads are divided into sections and put under the charge of a trained workman, who is held responsible for the general condition of the surface under his charge, and is supplied with a sufficient amount of material for making repairs and means of transporting it from one point to

another, is only just beginning to receive attention by our State highway commissions and engineers. The old aphorism that a stitch in time saves nine is particularly applicable to the maintenance of roads It will doubtless be found more economical in the long run to make frequent or even daily repairs, than to allow a road to completely disintegrate in the course of a few months or years, and then reconstruct or resurface it.

CHAPTER XIV.

Street Sanitation, With Some Special References to New York.

WILLIAM H. EDWARDS, A.B.,
Commissioner of Street Cleaning, New York City.

The story of the Department of Street Cleaning should be frequently told citizens, so that when they criticize, as inevitably they will, they may criticize intelligently. We expect criticism, we want it, and we certainly get it. When one stops to

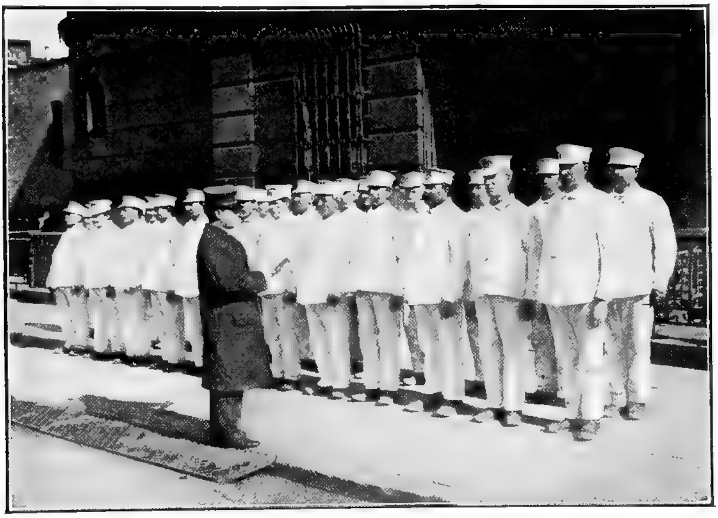

FIG. 117.—MORNING ROLL CALL AT A SECTION STATION IN THE DEPARTMENT OF STREET CLEANING, NEW YORK CITY.

consider that 6,500 men start out every morning on the big task of cleaning New York City's streets, each to do his individual share in cleaning and making them more sanitary, that the Department of Street Cleaning in New York is responsible for the cleaning of the surface of about 1323 miles of streets, and re-

moving ashes, rubbish and street sweepings from the entire Boroughs of the Bronx, Westchester, Riverdale and other outlying towns in that neighborhood, the Borough of Manhattan, and all Brooklyn, Williamsburg, Brownsville and Sea Gate, he may realize the vastness of the proposition. These forces are like nothing more nor less than doctors doing their share of keeping the death rate down. It might be interesting to the reader to know that the death rate in New York City during the past year was the lowest on record. It may be claimed with

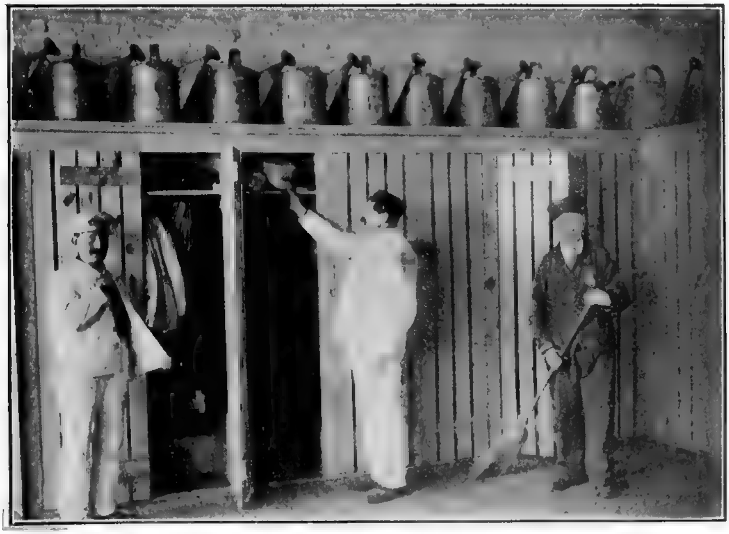

FIG. 118.—LOCKERS IN SECTION STATION, STREET CLEANING DEPARTMENT, NEW YORK CITY.

due modesty that the Department of Street Cleaning played no small part in producing such results.

The streets of our cities are used for a variety of purposes. They not only serve as arteries of travel, but also as places at which people of the most varied ages, inclinations and dispositions congregate for business, inspection, amusement, and a number of other reasons, all of which are the outcome of desire and need. Then, too, city streets are intimately joined to every household; the residents, of necessity, traverse them; they carry

dirt of the streets into their homes; and they secure their food and air through the streets. Both food and air are frequently contaminated. These contaminating matters consist of pulverized excreta and rejecta of animals and men, the factory wastes, and, to quote Soper,* "the product of the ceaseless wear and tear of everything perishable in the city."

FIG. 119.—DISTRICT ORGANIZATION, DEPARTMENT OF STREET CLEANING, NEW YORK: SUPERINTENDENT, FOREMAN, ASSISTANT FOREMAN, DRIVER AND SWEEPER.

The effects of city dirt are, in fact, perceivable everywhere. Ground by vehicle, animal and human contact into a powder, it is raised from pavements by the wind to be partly suspended in the air and partly to be distributed promiscuously. The dust, including soot, in suspension, discolors our bodies and clothing, and evidences of its deposition are found on stone monuments and buildings; it is this dust which blackens the snow, and in a penetrative form it enters offices, homes, schools and hospitals.

The streets of our cities are also the natural outlets for filth and refuse, organic and inorganic, of every conceivable nature.

*"Modern Methods of Street Cleaning," 1909, p. 7.

To be brief, street refuse may be conveniently classified as follows:

Street sweepings.	Animal manure; excrements. Pavement dirt; detritus from wear. Droppings from carts. Materials from building construction. Leaves and remains of fruit. Paper and rags. Wood, leather and rubber. Bottles, glass, and crockery. Sweepings from buildings, etc. Soot and general air dust.
Dead animals.	
Snow.	

FIG. 120.—STREET SWEEPER WITH WINTER CAP AND STORM SHIELD, NEW YORK CITY—A "WHITE WING."

The sources of street sweepings are likewise of a varied nature. Dust emanates from windows and doors when rooms are cleaned; rugs and carpets are beaten on roofs and on the pavements; human beings and animals cast their excreta on

the thoroughfares; and various refuse is thrown out into the gutters and streets.

The litter carelessly thrown on the streets amounts to much more than the ordinary individual appreciates. It is estimated that this addition to the work costs not less than $40,000 per annum. It is illegal, but, more than that, it is inexcusable. To

FIG. 121.—SWEEPER DEPOSITING SWEEPINGS IN GUTTER (OLD METHOD), NEW YORK CITY.

this litter is added the refuse dropping from vehicles transporting all kinds of materials. Frequent warnings do not seem to correct this useless offense, but occasional arrests of the offender prove more or less salutary. To obviate this nuisance the Department places cans at frequent intervals for the reception of all such materials, and frequent appeals are made to the citizens for help.

Each building which is wrecked or erected adds to the street dirt; each conveyor of building materials and refuse contributes materially; and the sidewalks and pavements give up their share of eroded, worn and torn material.

The greatest amount of street dirt which becomes scattered upon sidewalks and pavements is caused by the movements of vehicles and the contributions of horses; these are constant sources of street dirt which cannot be avoided. In fact, the quantity of horse dung which may be deposited on a mile of

city streets is quite large, and the residue of this excreta is a large ingredient of city street dirt.*

The physical appearance of street dirt is very variable. Some of the components are rejecta which may be removed by hand tools (shovels, push scrapers and brooms); paper, manure, wood, bottles, etc., belong to this class. Other portions and constituents of street dirt exist in too fine a state of division to permit of hand removal; ashes, sand, coal dust and manure residues come under this head, and such finely divided material is the most difficult and expensive variety of street waste to handle.

FIG. 122.—SWEEPERS WITH BROOMS AND BAGS (NEW METHOD).

This material forms a mud in wet weather; and when it is dry and windy, it is variously transposed in the form of annoying dusts. It is, therefore, desirable to get rid of this material. The method of doing this is fairly simple, provided sufficient funds are available; but such is rarely the case, and then it is indeed a problem.† It is dependent upon the nature of the

*One thousand horses will, in every working day of eight hours, deposit about 500 gallons of urine and 10 tons of dung upon the pavements. "On the Utilization of Stable waste," see Birchmore, *Journal of the Society of Chemical Industry*, 1900, vol. XIX., p. 118.

†For cleaning all the boroughs of garbage, ashes, refuse and street sweepings the Board of Estimate and Apportionment allowed an appropriation of $7,418,299.20 for 1909, and this amount was divided among the boroughs, Manhattan receiving $4,230,441.70; the Bronx, $560,371.30; Brooklyn, $2,492,481.20; and for General Administration, $135,005.

pavement, the quantity of dirt to be handled and disposed of, the uses to which the street is put, the water supply, labor conditions, and the sewerage system, which subjects are discussed in other chapters.

There are two general methods for disposing of street dirt; namely, it may be picked up, swept up, or shoveled up, and then hauled away, or it may be washed into sewers through the

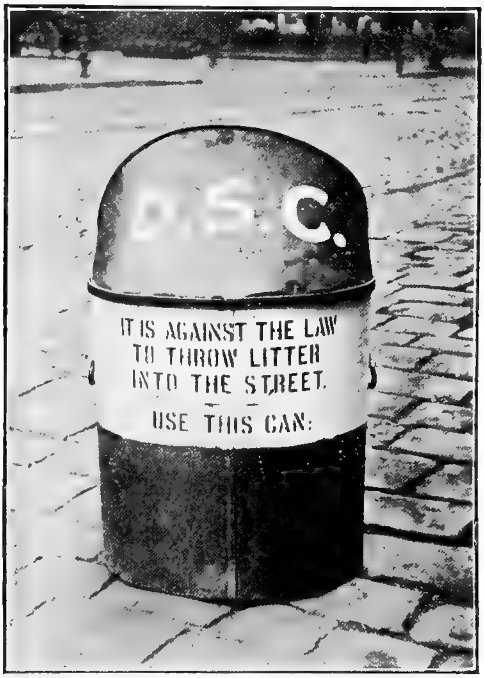

FIG. 123.—STREET CAN FOR LITTER.

agency of water, or there may be a combination of these methods.* As a rule, a considerable portion of the dirt is conducted away by sewers during rain storms. Some cities have especially constructed their sewers with the view of conducting off all dirt which can be reasonably emptied into them; in fact, it may be said that many municipal engineers consider that the sewerage system of a city should be constructed in such a way

*The three following chapters deal more specifically with the problems of washing the streets and utilization of the wastes.

that it will carry off a large portion of the fine dirt from the streets.

The snow, which calls forth the muse of budding poets and helps the small boy to make life miserable for the pedestrians, brings its large share of trouble to the Commissioner of Street Cleaning. Traffic must not be impeded, for people must go and come in their business travel. The question of how best to ac-

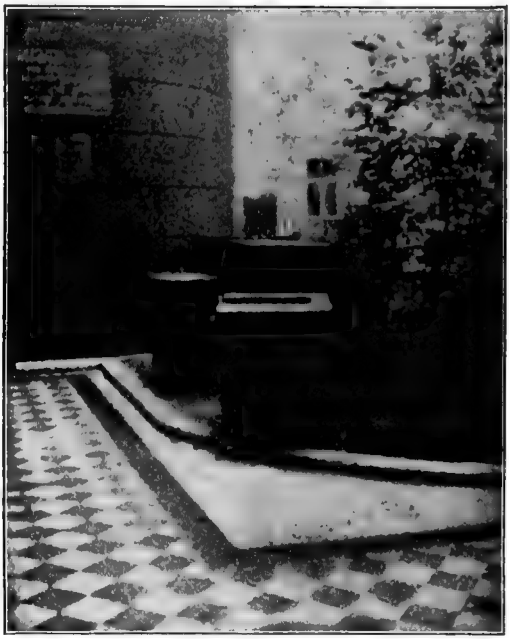

FIG. 124.—CHARLOTTENBURG, NEAR BERLIN, GERMANY. RECEPTACLES FOR THE SEPARATE COLLECTION OF KITCHEN WASTE, ASHES AND PAPER. (Courtesy of Dr. Soper.)

complish the removal with regard both as to speed and economy is always a hard one and is becoming more difficult all the time, especially in New York, as the stables move uptown or out of town and the cost of trucking soars higher. Plows or scrapers which throw the snow to the sides of the streets give a passageway in short time. But the public is not patient and must have the snow entirely removed, so it must be piled and loaded and carted away at a considerable expense, which is estimated in

FIG. 125.—SWEEPERS PICKING UP LITTER, USING BAGS.

FIG. 126.—CITY OF WESTMINSTER. ORDERLY WITH HANDCART—PICCADILLY. (Courtesy of Dr. Soper.)

FIG. 127.—HAMBURG, GERMANY. STREET CLEANER WITH HIS APPARATUS ABOUT TO EMPTY A HANDCART FULL OF STREET SWEEPINGS INTO A TEMPORARY STORAGE PIT BENEATH THE SIDEWALK. (Courtesy of Dr. Soper.)

FIG. 128.—SWEEPER WITH FULL EQUIPMENT, NEW YORK.

New York at about $35,000 per inch of snowfall. This large expense in New York is due in part to the dumping points being

FIG. 129.—WAGON FOR CARRYING SWEEPERS' CANS, NEW YORK.

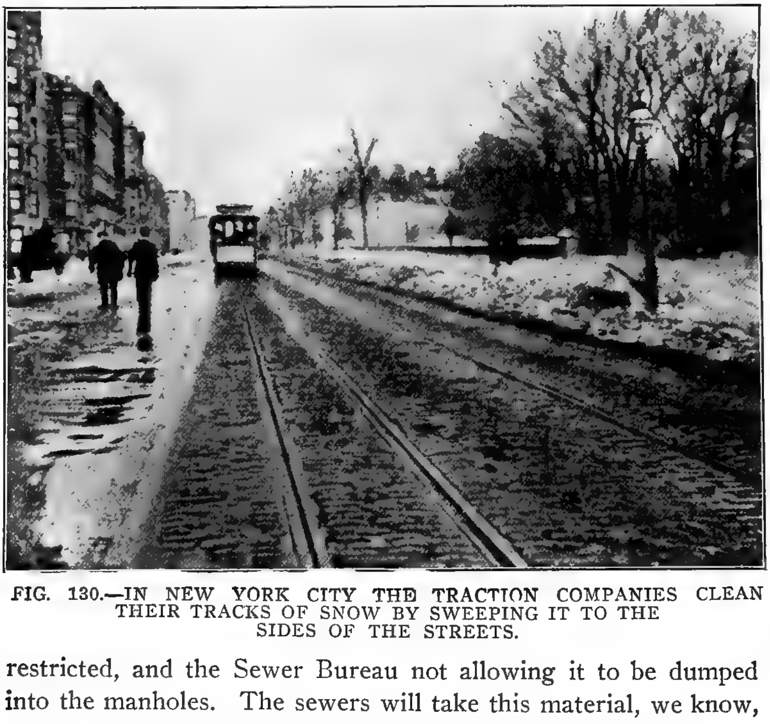

FIG. 130.—IN NEW YORK CITY THE TRACTION COMPANIES CLEAN THEIR TRACKS OF SNOW BY SWEEPING IT TO THE SIDES OF THE STREETS.

restricted, and the Sewer Bureau not allowing it to be dumped into the manholes. The sewers will take this material, we know,

and, if not, they should be so constructed as to take it; we hope to have aid in this direction when next winter sets in.

FIG. 131.—FIVE-WHEEL SNOW PLOW, NEW YORK.

FIG. 132.—FOUR-WHEEL SNOW PLOW, NEW YORK.

Many devices for melting the snow on the streets have been proposed, but so far no effective machine or method has ap-

peared. In Paris, $4\frac{1}{2}$ ounces of common salt per square yard have been used for a fall of two inches. Here is an excellent opportunity for some chemist to do good and also become wealthy.

FIG. 133.—DUMPING SNOW AT WATER FRONT, NEW YORK.

FIG. 134.—AUTO SNOW TRUCK, NEW YORK.

Local topographic conditions must largely influence the methods applied to keep a city clean. It is wise to spend money in

experimental work in seeking the best solution. There is no other way to clean the streets except by water or suction, which removes all dust from the surface of the streets. The dust pest is surely a great nuisance which must be got rid of. Suction is out of the question on account of the expense, so to make the streets cleaner the use of water seems to be absolutely necessary. Through the instrumentality of power machines, water has been found to be the real effective agency. New York City has

FIG. 135.—EMERSON VACUUM STREET CLEANER.

made the most exhaustive tests of these machines, and after testing 35 machines for 100 consecutive days at a cost of $60,000, it is believed that we are in a position to systematize such methods as to improve conditions 100 per cent. and benefit the health and increase the happiness of all.

Especial attention should very properly be given to the cleaning of the streets over which parades or pageants are to pass in order that no unsightly appearance of the street will detract from the pleasure of those participating, either as actors or spectators, and that the comfort of all may be promoted. Incidentally, the public takes much pride in the display and places less obstacles in the way of the Commissioner who is carrying out big plans for the welfare of the citizens.

CHAPTER XV.

Methods of Street Cleaning and Waste Disposal of the City of New York.

EDWARD D. VERY, C.E.,
Sanitary Engineer, Department of Street Cleaning, New York City.

The problem of disposal of city wastes, exclusive of sewage and dead animals, is one which deserves a most careful attention and the best efforts towards solution. This problem has always existed and yet up to the present time very little effort has been made to arrive at a proper solution, but the various municipalities have allowed the matter to be handled in a slipshod and unbusinesslike and uneconomical manner. Spasmodic efforts have been made by municipal officers in isolated cases, such as that of Colonel Waring in New York City; but the matter has not been followed up in a systematic way, and even here we have neither progressed nor improved on the original primitive methods. The subject has two sides: the sanitary and the economic. The sanitary side is taken up principally by the putrescible wastes; the economic includes the non-putrescible.

For convenience Colonel Waring divided the wastes of New York City into three classes, viz., ashes, garbage and light refuse, and rubbish. In other places the word garbage is indiscriminately applied to the whole, and there is, therefore, a primal confusion in the misunderstanding of terms. Therefore, for our purposes I shall use our New York classification.

Ashes are defined by the Sanitary Code as "cinders, coal and everything that usually remains after fires;" but for the general convenience of the householder and the city work, the Department of Street Cleaning includes in this class: ashes proper, sawdust, floor sweepings, street sweepings, bottles, broken glass, broken crockery, tin cans, and oyster and clam shells. *Garbage* is defined by the Sanitary Code as "swill and every accumulation of both animal and vegetable matter, liquid and otherwise, that attends the preparation, decay and dealing in, or storage of, meats, fish, fowls, birds or vegetables"; the Department of Street

Cleaning classes under this head: kitchen or table wastes, vegetables, meats, fish, bones, fat and fruit. *Rubbish* is defined by the Sanitary Code as "all the loose or decayed material and dirt-like substance that attends use or decay, or which accumulates from building, storing or cleaning"; the Department of Street Cleaning classes under this head: paper, pasteboard, etc., rags, mattresses, carpets, old furniture, oilcloths, old shoes, flower stems, leather and leather scraps, tobacco stems, straw and excelsior. Because of the methods adopted by the Department, these materials are separated by the householder and are collected separately by the carts of the Department or by private carts engaged in this work. This matter of separation is necessary when utilization of the ashes and rubbish and reduction of garbage is resorted to. Where destruction or cremation is the method, mixed materials are not only unobjectionable, but rather necessary.

It is rather a criticism on the general lack of thought of the people served that the question of disposition is considerably affected by the fact that people do not want to separate their wastes. If one considers the small amount of time and trouble necessary to separate the various materials at the house, it is hard to understand why the subject should be made so much of in the way of objection. Yet one of the hardest parts of the Department work is to enforce the proper separation by householders. This is particularly true in what is commonly known as the tenement house district, where one can for refuse is used by many families in common. The tenants are blamed, but from my observation I find that the owner is more to blame, as he is required by the law to provide sufficient receptacles for a thirty-six hours' receipt from his building.

There is a system of private cart collection which takes up part of the wastes from parties who do not care to comply with the Department rules as to time and place of putting materials for collection by regular service, or else who have materials which the Department will not collect, but which will be received at Department dumps. These private carts are given permits to dump their materials at the regular dumps and are under the rules of the Department as to separation and classification.

In 1909, the Department received at the dumps of the various Boroughs, 2,497,779.75 cartloads of ashes, containing approximately 4,255,868 cubic yards and weighing approximately 2,340,727 tons; of garbage, 332,764.50 cartloads, approximately 565,702 cubic yards, and weighing approximately 311,136 tons; of refuse, 320,264.50 cartloads, approximately 2,401,984 cubic yards, and weighing approximately 160,132 tons. These data show that the receipts are proportioned approximately as in bulk: ashes 59 per cent., garbage 8 per cent. and rubbish 33 per cent.; and in weight: ashes 83 per cent., garbage 11 per cent. and rubbish 6 per cent.*

The amounts of the different materials carried by the private cartmen proportioned: ashes 26 per cent., garbage 5 per cent. and rubbish 5 per cent.; which left the Department service as carrying: ashes 61 per cent., garbage 10 per cent. and rubbish 6 per cent. Of the materials carried under the head of ashes the best estimate seems to give the bulk of the street sweepings to be about 20 per cent., so that the true classification for Department work should be reduced to 49 per cent. ashes, 12 per cent. street sweepings, 10 per cent. garbage, and 6 per cent. rubbish.

The ashes proper are divided into two classes, viz., household ashes and steam ashes. Household are such as are given off from the ordinary heating and cooking operations, steam ashes from large heating and power plants. There is no definite knowledge of the proportion of these two classes, and I find that it has been generally assumed that the materials carried as ashes by private carts are steam ashes. This, however, is not the fact, as private cart service is extended to ordinary householders as well as large apartment houses and factories. An estimate might be made if all the steam ashes were delivered to the dumps of the Department, but the use of this material in building operations leaves an undetermined quantity which makes calculation impossible.

By a test made by the Department it was found that in 1,000 cartloads of ashes there is an average of 10 tons of tin cans, 2,400 pounds of paper, 3,000 pounds of rags, 11,000 bottles, 55 barrels of broken glass, 300 empty barrels, 2 tons of old iron,

*The month of March gives the maximum monthly amount of ash receipt, viz., 256,915 tons; August the minimum amount, viz., 138,995. For garbage August has the maximum monthly receipt, viz., 32,750 tons, and February the minimum, viz., 17,005 tons. For rubbish July has the maximum, viz., 14,887 tons, and February the minimum, viz., 10,024 tons.

and 836 pounds of rubber and miscellaneous metals. Steam ashes are clean and free from fine ash. Household ash is composed of about 45 per cent. of fine ash, 30 per cent. of clinker and coarse ash, and 25 per cent. of unburned or partially burned coal.

The street sweepings on the average are composed of 37 per cent. moisture, 31 per cent. of organic matter, and 32 per cent. of inorganic matter.

Garbage is on the average composed of 70 per cent. moisture and 30 per cent. solid material. In the nature of things garbage varies considerably in its composition, due to seasons and the habits of the people.

Rubbish is composed of the assortment which is listed above and a test for some time gave an average result for 1,000 cart-loads: 9 tons of tin cans, 80 tons of paper, 16 tons of rags, 9,600 bottles, 47 barrels of broken glass, 3,000 empty barrels, 9 tons of old iron, 1,700 pounds of rubber and miscellaneous metals. There have been attempts to find the average waste per capita in each class of material, but such an average cannot be obtained with any degree of accuracy because the wastes are not all received at the dumps. As has been stated, the steam ashes during the building season are used elsewhere; as to household ashes, when they are mixed with garbage they are taken to private dumps, and the record is lost. Then, too, where hauls are excessive it is cheaper to pay for their deposit on private scows than to take the time to ride to Department dumps. The garbage of hotels and restaurants and large apartment houses is sold to swill men, who ride it out of town, and there is no record of amounts. Rubbish is gathered by junkmen and by charitable associations, and no method has been found to approximate the amounts of materials so disposed of.

The story of wastes having been recited, the reader will be impressed with the fact that this is far from being an exact science. If one gets the reports made by city officers, commissioners and others who are investigating this problem, he will find that the quantities and qualities are so varied in different localities that a special study of each case is absolutely necessary. Where data are being compiled, the compiler asks of others information of such a general nature as to make the compilations practically useless, and the resulting conclusions are valueless

because of the failure to take into consideration all the facts which affect the nature of the question. By a study of the various sections of the Borough of Manhattan this variation is strongly brought out, and one engaged in the work here early learns to avoid general statements. However, the matter is being garbled continually and reports are made in technical papers with incomplete data. City officials only too often take these

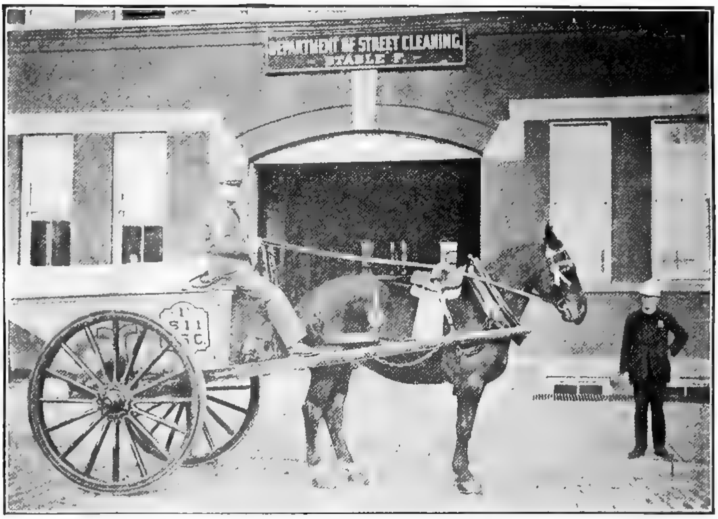

FIG. 136.—ASH AND GARBAGE CART WITH CANVAS COVER, NEW YORK.

facts as presented, invest in expensive plants, and fail. All of which goes to show that there is often a distinct need of legitimate reform.

For the purpose of administration of the Department work, the Boroughs are divided into Districts, which are subdivided into Sections; each District is in charge of a District Superintendent and each Section is in charge of a Foreman. Manhattan is divided into 11 Districts and 59 Sections; the Bronx has 2 Districts and 5 Sections; and Brooklyn has 8 Districts and 40 Sections. The force of sweepers employed in cleaning the streets is approximately 2,650, and they have routes which vary according to the conditions of the traffic and the habits of the inhabitants. The area cleaned per man varies from 8,000 square

yards to 14,000 square yards. The area kept clean is extended over 1,359 miles of paved and macadamized streets, having an approximate area of 23,918,400 square yards. These men are equipped with a broom, scraper, can carrier and shovel, and they remove the litter and street dirt, deposit them in the cans which are placed along the sidewalk, and later the contents of the cans are dumped into carts and taken to the ash dumps.

FIG. 137.—RUBBISH CART, NEW YORK.

As an adjunct and for the purpose of obtaining more efficient work, the Department uses horse-drawn sweeping machines preceded by a sprinkling wagon, hose flushing and machine flushing. The sweeping machines will average 70,000 square yards in a day of 8 hours at an approximate cost of 32 cents per 1,000 square yards; hose flushing averages 25,000 square yards in a day of 8 hours at an approximate cost of 65 cents per 1,000 square yards; machine flushing is done by machines which are tank wagons so constructed that air is compressed in the introduction of the water during the operation of filling, which air, when the water is released, causes a pressure which forces the water so as to effectively scour the pavement. This is more effectively done by the use of a nozzle so designed as to shape

the stream in a chisel form. These machines will clean about 30,000 square yards in an 8 hour day at an approximate cost of 39 cents per 1,000 square yards, with the use of approximately 400 gallons of water per 1,000 square yards. There is also an effective machine to be used on smooth pavements known as the "squeegee," which is composed of a tank wagon with a spiral rubber scrubber attached; the machine sprinkles and

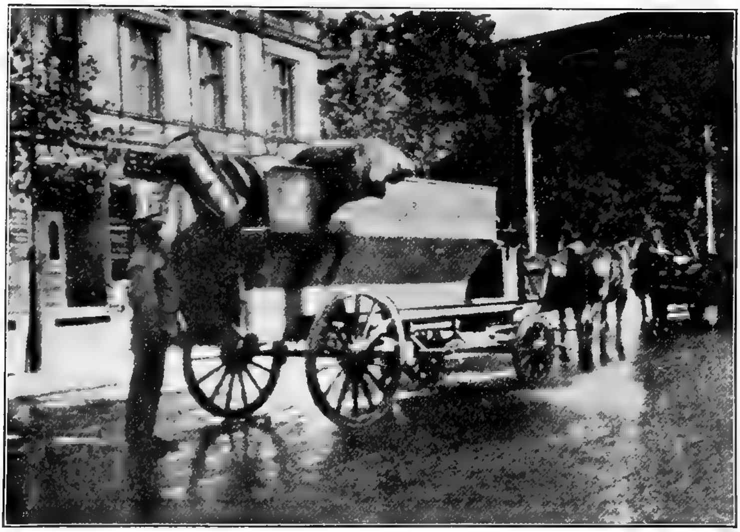

FIG. 138.—CHARLOTTENBURG, NEAR BERLIN. HOUSE REFUSE CART WITH CAN OF REFUSE BEING EMPTIED BY A MECHANICAL APPLIANCE WHICH PREVENTS THE ESCAPE OF DUST AND ODOR. (Courtesy of Dr. Soper.)

scrubs the pavement and delivers to the side a windrow of material which can be collected later; this machine will clean approximately 50,000 square yards in an 8 hour day at an approximate cost of 21 cents per 1,000 square yards, with the use of approximately 200 gallons of water per 1,000 square yards. With the use of flushing machines, squeegees and hand labor combined there would be reason to believe the condition of the streets would be greatly improved, and such a system is now contemplated by the Commissioner.

There is a natural fouling of the street surface and an unnatural fouling. The natural comes from excrement from ani-

mals, detritus from wear of pavements, soot and dust from the air, leaves from the shade trees, and the grindings from tires and shoes. The unnatural, or, rather, avoidable causes are: refuse thrown or swept upon the streets from buildings, refuse thrown by careless users, and refuse spilled from vehicles carrying materials through the streets. The latter causes are supposed to be prevented by the operation of ordinances which are

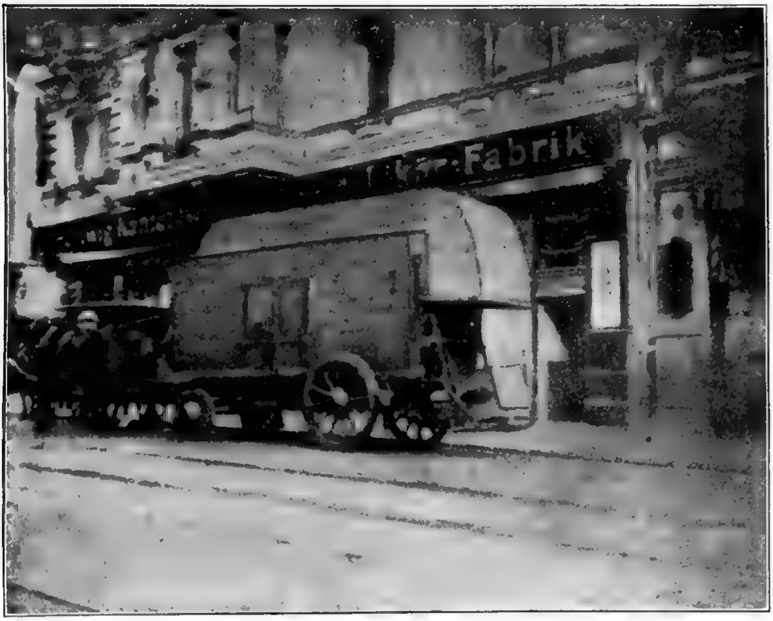

FIG. 139.—COVERED WOODEN CART USED IN BERLIN, GERMANY, TO COLLECT HOUSE REFUSE. THIS CART IS INTENDED TO BE DUSTLESS AND ODORLESS. (Courtesy of Dr. Soper.)

honored in the breach, and these causes result in the greater cost of cleaning, as the sweeper has considerable work in collecting litter before attacking the dirt, and the material is bulky. Owners of buildings are supposed to place their sweepings with the ashes in the proper receptacles. The Department places at frequent intervals large cans for the deposit of paper and like refuse and fruit skins, but with poor result, as they are overlooked by the average person.* Vehicles carrying loose materials

*All of which serves to emphasize the need of constant education in regard to the simplest of matters.

are supposed to be so loaded as to avoid spilling the contents, but the endeavor to carry large loads results in the division of

FIG. 140.—SWEEPING MACHINE, NEW YORK.

FIG. 141.—HAND HOSE FLUSHING, NEW YORK.

the carter's labor with the Department force, to the detriment of

the Department's work. The amount of this avoidable material varies in the different sections of the city, but the average is large in comparison with the unavoidable. With the advent

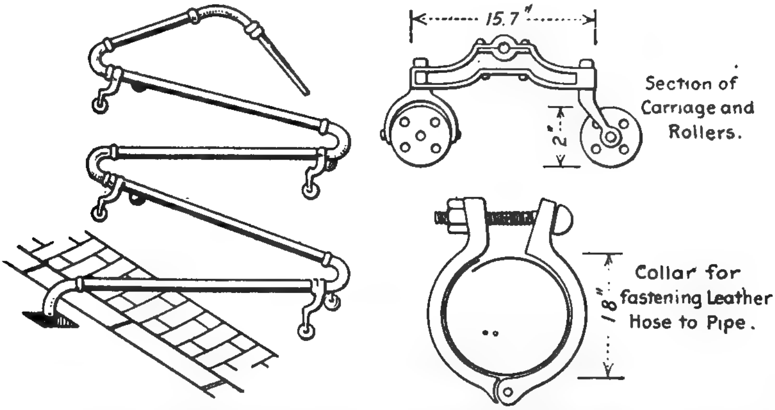

FIG. 142.—HAND HOSE AND METAL PIPE ON ROLLERS USED FOR FLUSHING STREETS, WASHINGTON.

FIG. 143.—SQUEEGEE IN OPERATION, NEW YORK.

of the automobile traffic there is a considerable addition to the ordinary wear, as material is drawn under and then spread. The construction of high office buildings, with the consequent

FIG. 144.—ELECTRICALLY DRIVEN MACHINE USED IN BERLIN, GERMANY, FOR CLEANING STREETS. (Courtesy of Dr. Soper.)

FIG. 145.—CONNELLY FLUSHING MACHINE.

large heating plants, is causing a large addition from soot and dust from the chimneys.

The wastes are collected in carts of a pattern found best

FIG. 146.—STUDEBAKER FLUSHING MACHINE WITH GASOLINE ENGINE AND PUMP.

FIG. 147.—SAND SPREADER.

applicable to this city's needs. The ashes and garbage are collected in metal carts and the refuse in wooden carts. The force engaged in this work is approximately 1,200 men. Each driver

has a route on which he collects daily, beginning with a load of ashes; he collects ashes until the people put out their garbage, which he collects, and then returns to his collection of ashes. The average haul per cart is about two miles, and the average number of trips per day is five. Street sweepings are collected with the ashes as the driver goes over his route. The materials are taken to the Department dumps in Manhattan and the Bronx, and in Brooklyn to the dumps of the contractors for final disposition.* In Manhattan and the Bronx there are 13 dumps

FIG. 148.—DUMPING INTO SCOWS, CANAL STREET, NEW YORK.

*For the five years previous to 1909 the removal of ashes, rubbish and street sweepings was done by the American Railway Traffic Company which, in conjunction with the Brooklyn Rapid Transit Company, operated fifteen inland railroad rubbish stations. The company handled all matter delivered at these stations for 34 cents per cubic yard, transporting all the refuse (after salables had been removed) to property which the company was filling in on the outskirts of the Borough. On the call for bids, the American Railway Traffic Company increased its bid to 44 cents, while the Borough Development Company submitted a bid at 34½ cents per cubic yard. The Commissioner took the matter up with the Borough Development Company, and also with the Board of Estimate and Apportionment, and the company was awarded the contract. Not only the price per cubic yard was considered, but also the location of the different dumping stations which the Company offered with regard to the haul. It was appreciated that the cost for cartage would be more under this contract, as it called for an increase of 68 in the number of carts in Brooklyn, but even with this addition the cost of ash disposal is not so great as it would have been under a continuance of the contract with the American Railway Traffic Company at the advanced price. There are now three inland stations, seven waterfront stations, and six railroad stations. Two companies have the contract for removing ashes and sweepings from the water front dumps of Manhattan and the Bronx for filling in Riker's Island. There are five different sizes of scows, the load carried by the smallest of which costs the city $68, and that carried by the largest $105, the average price being 17 cents per cubic yard.

along the water-front, located from ¾ of a mile to 4¼ miles apart. In Brooklyn there are 10 water-front, 6 railroad and 3 inland dumps. The water-front dumps are designed so as to allow the material to be deposited in the center of the scow, so that it may be drawn to either side to trim the scow, assuring floating on an even keel. This is done by making a cantilevered platform, which is 3 feet less than the width of the scow. In the railroad dumps the material is dumped directly into the cars

FIG. 149.—SCOW LOADED WITH RUBBISH.

without any overhang. In the inland dumps the material is dumped on a belt which conveys it to an overhead bin, from which it is dropped into large relay trucks, which carry it to the water-front dumps.

For the final disposition of the garbage in the three boroughs a contract is let, the terms of which are for five years. The contractor furnishes the scows and receives the material from the tail of the cart, transports it to the reduction plant at Barren Island in Jamaica Bay and there disposes of it by the Arnold-Egerton process of reduction, which will be described in the next chapter.

In Manhattan and the Bronx the ashes and rubbish are received on scows furnished by the contractor, but loaded and trimmed by the city. The loading and trimming is done under a contract, by the terms of which the contractor furnishes the labor necessary to perform the work, and he is allowed to reclaim any valuable or salable materials and appropriate them to his own use; for this privilege he pays the wages of his labor, the salary of the inspector, and in addition a cash payment of $1,717 per week.

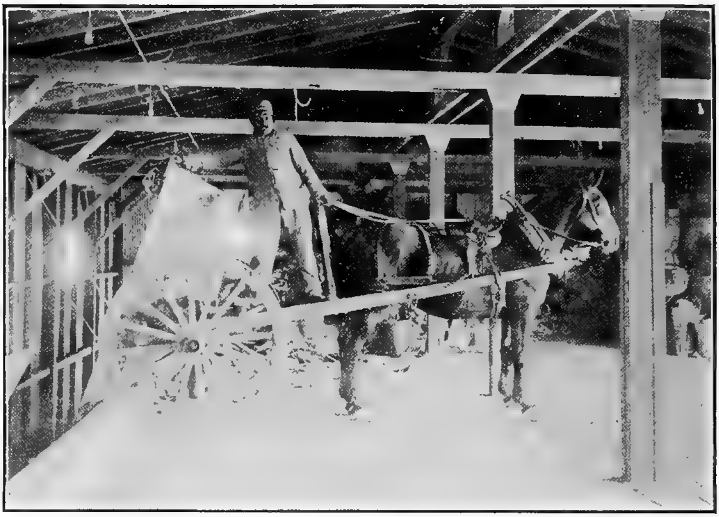

FIG. 150.—CART DUMPING IN COVERED DUMP, BROOKLYN.

The contractor for final disposition takes the loaded scows away and unloads them. From 50 per cent. to 60 per cent. of the material is taken to Riker's Island, where it is put into a fill to enlarge the area of the island. This island was originally 87 acres in area, to which we have added 63 acres, and at present we are adding 173 more. The remainder of the material is the property of the contractor, who puts it in land fills outside of city property under contracts with private owners.

In Brooklyn the contractor furnishes the dumps and dumping places and all the plant for handling the materials, which become his property from the tail of the cart. He picks the sal-

able rubbish and incinerates the unsalable rubbish, and uses the ashes for land fill under contract with private owners.

Thus the wastes are collected and disposed of, and so the streets are kept clean at an average cost per capita of the whole service of about $1.70.

CHAPTER XVI.

Waste Disposal by Utilization.

EDWARD D. VERY, C.E.,

Sanitary Engineer, Department of Street Cleaning, New York City.

In the final disposition of municipal wastes other than sewage, those engaged in the work are divided in opinion as to the better method, i.e., utilization or destruction. In this chapter the utilization of city wastes will be considered.

While in the manufactures it has been found profitable to utilize the wastes, or by-products, to great financial advantage, there seem to be but few who can appreciate the possibilities of the utilization of cast-off or waste products from households or from the furnaces of manufacturers. And yet those who have delved in this subject at all are amazed at the boundless opportunities which have been overlooked altogether or but slightly entered into. Sentiment has attached to the disposition of garbage (used in this case to cover all the wastes) but one method, and that is destruction. The average person only considers the waste as a noxious material which must not be rehandled, but which must be destroyed to prevent disease breeding. But the official who finds the expense attached to the disposition to be a continually increasing burden on the community, longs to find some economical method of performing his duty which may decrease the expense. Here enters the utilitarian, who pushes aside the curtain and discloses the various methods whereby money may be returned to the fund by a sensible use of the valuable portions of the wastes, and that valuable portion is growing larger and larger as the investigations are carried on.

Ashes are divided into two classes, the household ash and the steam ash. Household ash is the product of the kitchen range or the ordinary heater. Analysis of this material by an average sample shows the following composition: moisture, 0.83 per cent.; volatile combustible matter and fixed carbon, 35.44 per cent.; and true ash, 63.73 per cent.* Here we have

*From analysis made by Mayor's Commission on Street Cleaning and Waste Disposal, New York City, 1907.

35.44 per cent. of combustible material which can be reclaimed for use as a fuel. Now, when we put this figure into tons disposed of in 1909, we find it will give us about 673,533 tons of this usable fuel which may be reclaimed. For the reclamation of this coal a process has been devised which includes the washing to bring out the coarse materials from the fine and then the passing of the coarse materials through a series of screens, which allows of the separation of the good coal, partially burnt coal and the clinker from each other so as to give the three grades separately. Tests of the heating value of this reclaimable coal have given the following results: With new coal having an average unit heating value of 11,000 B.T.U., where 20 per cent. of the ashes was reclaimed as combustible, there was found an average unit heating value of 8,000 B.T.U., and where 35 per cent. was reclaimed the test gave the average unit heating value of 5,000 B.T.U.* The inventor of this process claims that the cost per ton for this work, including interest charges, depreciation, operation, etc., will be not to exceed $2 per ton. So we find that our 673,533 tons of reclaimed coal, having a heating value of 50 per cent. of new coal, cost less than 50 per cent. of new coal. Now we have left 63.73 per cent. of an original material which is a true ash. This fine ash, with the addition of lime and other constituents, may be made into a merchantable Portland cement. This process is now being developed and tests of the resultant product have proven the material to be of a high grade, and from the experiments it is believed that the cement may be made at a very reasonable cost. The coarse ash, of course, may be reduced to fine ash by grinding. The mixture of this fine ash with the lime, etc., would seem to be a difficult operation, but it has been found that an intimate mixture is obtained with reasonable ease. Then, too, this fine ash may be used in combination with common brick clays, which, when burned, gives a slow vitrifaction which makes the resultant brick an excellent quality of paving brick at a reasonable cost. Tests of brick made by this process have given an average water absorption of 1.3 per cent., and an abrasion test of 1,800 revolutions in a 20 x 28 inch foundry rattler at 28 to 30 revolutions per minute showed a loss of 16.7 per cent. in weight. When it is

*Morse, "The Collection and Disposal of Municipal Waste."

remembered that the standard test is 3 per cent. for water absorption and 20 per cent. for abrasion, these tests show a favorable result. Ornamental tile, too, have been made from this material, though I am not aware that this line is being pursued at this time. Chemical analysis of an average sample of ashes shows that it has the following: phosphoric acid, 1.25 per cent.; potash, 1.64 per cent.; and nitrogen, 1.85 per cent. High grade commercial fertilizer should have phosphoric acid, 9 per cent.;

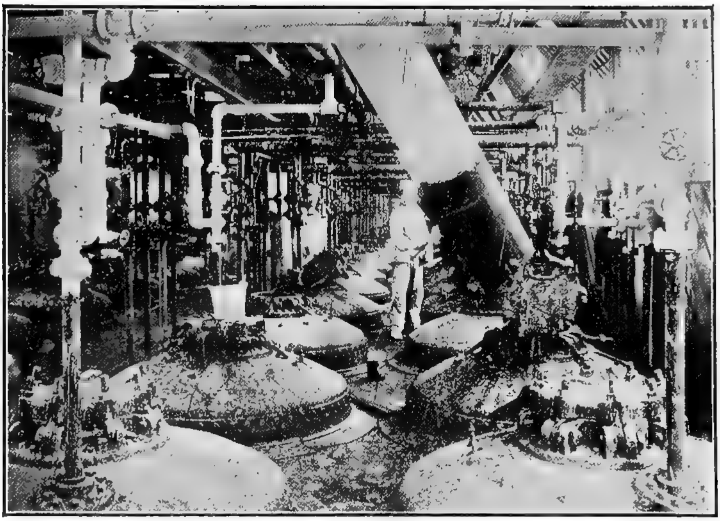

FIG. 151.—CHUTES TO DIGESTERS AT GARBAGE PLANT, NEW YORK.

potash, 10 per cent.; and nitrogen, 4 per cent.; low grade should have phosphoric acid, 8 per cent.; potash, 2 per cent.; and nitrogen, 2 per cent.* Now, ashes have an absorbing power of approximately 125 per cent. This, then, gives a good base for a fertilizer, so that with the addition of the necessary chemicals in some convenient form a fairly cheap plant food is obtained. There is a scheme for taking the cesspool materials of small communities, and by mixing and drying the resultant, the sewage disposal is properly accomplished and the fertilizer that is made will assist materially in making the cost very reasonable.

*United States Dept. of Agriculture, Bulletin No. 44.

The steam ash or coarse ash from power plants is of use in the building trades. It comes into play from forming a base to the sidewalk construction, which gives a nearly perfect drainage, through the filling of sound and fireproof walls and arch filling, to the making of floor slabs in reinforced concrete construction. Its use for these purposes is no longer speculative, and to-day in this city we find that not enough of this material is at hand to meet the demand. It must be clean and free from the other waste products to be usable, and when so clean de-

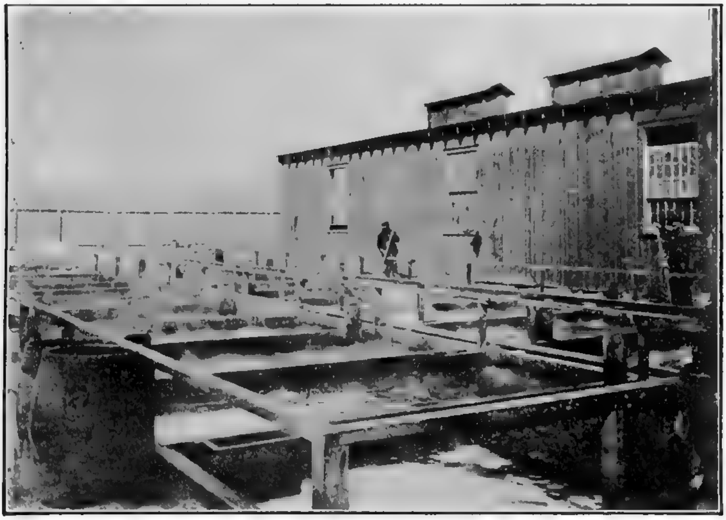

FIG. 152.—GREASE BASIN AT GARBAGE PLANT, NEW YORK.

mands a good price in the market. Its use is endorsed by building experts and fire underwriter rules, and its standing as building material is assured.

It would seem that street sweepings would make a good fertilizer; but experiments have shown that this form of waste is without profitable fertilizing value. This material used to be put in bags and shipped to the farmers in the vicinity, but they found the material so poor in quality that they even refused to pay the freight on it. A chemical analysis of this material shows as follows: phosphoric acid, 0.79 per cent.; potash, 0.73 per cent.; nitrogen, 1 per cent. Now, this shows a low

grade of fertilizing value; and when we remember that 31 per cent. of the material is inorganic matter composed of dust, grindings from pavement, and iron filings from horses' shoes and vehicle tires, it is easy to see that the fertilizing value is greatly offset. If the system of washing the streets with flushing machines and keeping them fairly free of inorganic dust is put in force, there is reason to believe that the street sweepings collected in the regular cleaning of the streets will have a much larger value as fertilizer because of the predominance of manure.

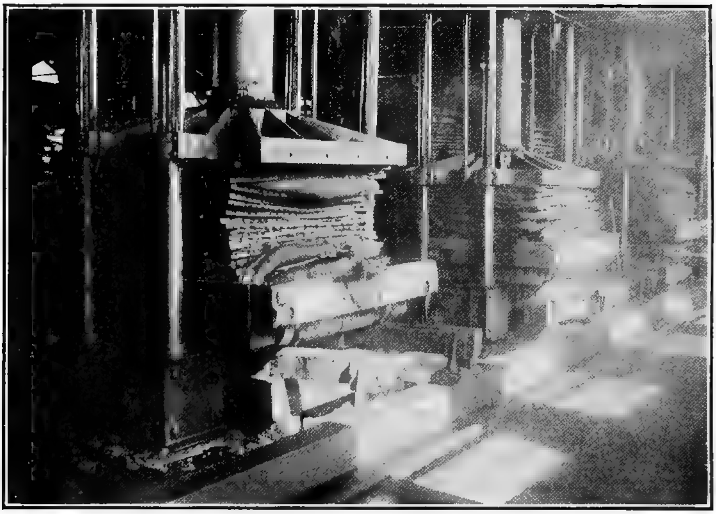

FIG. 153.—HYDRAULIC PRESS FOR GREASE RECOVERY AT GARBAGE PLANT, NEW YORK.

The paper and rags separated from the ashes or found in the rubbish have a class by themselves in the paper-stock trade, and there is a fairly steady demand for them, as they are extensively used in making paper-board. Tin cans are de-tinned and de-soldered for the reclamation of tin and solder, though of late the improved methods of manufacture of tin cans is reducing the tin and solder to such an extent that this saving is producing less and less valuable material. The cans are now rolled into sheets of tin from which buttons are punched out and used as washers in nailing down tar or building paper. The residue is melted down and used in making sash weights. The sheets

are frequently used in making filling for walls in fire and burglar proof safes. This gives a material hard to drill through on account of the number of laminations.

The registered bottle, such as milk and beer bottles, are of considerable value and are the property of the persons or firms whose names are blown in the glass, but they must pay a considerable price for their reclamation. The other bottles and broken glass, if of a good color, can be re-melted and re-blown; if not, they are broken up and used in making artificial stone or

FIG. 154.—SEA DUMPING.

tile. Empty barrels usually return to commission merchants to be used in distributing vegetables. Old iron goes into low grade castings. The other miscellaneous materials are used in as many ways as they have classes.

Garbage, the swill or food waste, is a putrescible waste which must be at least sterilized within a few days of its receipt for disposal. It has been used as a very crude form of fertilizer by spreading, in the raw state, upon farming lands and then ploughing it in. Burial in large holes is also resorted to. In both these operations it is found that the material does not become destroyed within any reasonable time—the absence of air results in failure to break down the structure of the material. Not long ago an excavation made in the vicinity of Rome, which was on the site of an offal dump of some 3,000 or

4,000 years ago, brought forth such an effluvia from the putrid but undigested offal that work had to be stopped. We have found, where the material is mixed and used as land fill, that unless the ground cracks open it does not consume, and where trenching for sewer or water construction is made there is almost invariably a resultant epidemic of disease in the neighborhood. Where the earth does crack open, the steam from the consuming fire is very noxious.

After an exhaustive examination of the subject, Col. Waring, who was then Commissioner of Street Cleaning, decided that

FIG. 155.—DIRTY BEACHES FROM SEA DUMPING.

the best interests of the city would be served by the reduction of this material by one of the existing processes. The processes which were satisfactory then have been kept up to date by the adoption of improved machinery in the operation, and the work is done economically, quickly and in a sanitary manner without offense or nuisance. The average garbage is composed of 70 per cent. moisture, 3 per cent. grease, 20 per cent. fibrous material, and 7 per cent. refuse and rubbish. The process of reduction is performed as follows: The material is loaded into large tanks or digesters holding from 8 to 10 tons each; when loaded, these tanks are tightly sealed by bolted caps and steam

is introduced at about 70 pounds pressure, and the material is cooked in this manner usually about 8 hours (the time is varied as the character of the material may demand); when thoroughly digested, this material has about the consistency and appearance of apple butter. The next step varies as the different methods of reclaiming the grease demand. If pressure is used only, the material is emptied from the digesters into a large tank and from there into forms made up by building up layers of the digested material enclosed in burlap sacking upon slatted hori-

FIG. 156.—CLEAN BEACH (SAME AS FIG. 155); NO SEA DUMPING.

zontal partitions formed of lath-shaped wood built square and by crossing the slats; this structure is built on a car, and when of the workable hight is run under a hydraulic press, pressure is applied, and the moisture and grease are forced out through the coarse sacking slowly and the fluid falls into a sewer, which carries it to large basins in which it slowly passes through partitions having baffling boards; in this slow travel the grease gradually separates from the water and rises to the top. When this process is completed, the grease is pumped off the top of the water into receiving tanks, from which it is put into barrels for shipment. Where the naphtha process of grease reclama-

tion is used, the material from the digester is run into long cylindrical dryers, where by direct heat or steam jacket heat it is dried by the driving off of the moisture only. From the dryers the material is carried into large drums so constructed as to permit of rotation and agitation in such a way as to cause a dissemination of the naphtha; naphtha is then introduced and allowed to percolate slowly and thoroughly through the whole mass; in this percolation the naphtha takes up the grease and

FIG. 157.—UNLOADING GARBAGE ON OUTBOARD CONVEYOR AT GARBAGE PLANT, NEW YORK.

carries it along to another receiving tank, where, by heating, the naphtha is separated and taken off as a gas, later to be condensed and re-used. The grease is tanked and later barreled; the remainder of the digested material, which is the fibrous component of the garbage, is now dried and screened, and the result is a fluffy coffee-colored product which has a high absorbing power and contains a small amount of the plant food chemicals; this material is a good low-grade fertilizer or a base for a high-grade fertilizer. The grease reclaimed is in the shape of a brownish oil which is used in the soap-making industries. It consists of fatty acids, stearic, oleic and palmitic,

combined with glycerine, the proportions of its constiuents being somewhat variable, as discovered by frequent analysis. This grease is mostly shipped to Europe, where it seems to be used to better advantage, as the users there understand it better than in this country, though I am told the Cleveland reduction plant disposes of its output in this country.

Plants for utilization of garbage through the reduction process have been heretofore operated by private firms under contract, and only lately has a municipal plant been designed and operated by a municipality, that in Cleveland, Ohio. Opponents of this system have criticised private operators for not giving the details of their operation and result. The description of methods has been freely given and the results have been given out as fairly as the variableness would permit, and the reports from the municipal plant have done little more than prove the correctness of that which has been known. If the same reticence has been practiced by those who have introduced other methods of disposal, the information would have been more valuable because of its reliability, and many municipalities would have been saved large sums of money by the avoiding of devices which were based on theory with a lack of knowledge of the de-

FIG. 158.—UNLOADING SCOWS AT RIKER'S ISLAND, NEW YORK.

tails, and with final condemnation and relegation to the scrap heap.

There have been attempts to make gas from garbage burning, both illuminating and producer gas, but I have no details which would prove of value as to how these results may be attained or at what degree of economy.

In summing up the discussion of the reduction process a writer on the subject has epitomized as follows:*

FIG. 159.—UNLOADING MACHINE, RIKER'S ISLAND, NEW YORK.

"ADVANTAGES:

"1. The organic or putrescible matter of the garbage is extracted into compounds which are harmless—as grease and tankage (fertilizer base).

"2. It thus saves those components which have a material intrinsic value.

"3. The garbage is cared for in a sanitary manner. The cost is about $1.80 to $2.00 per ton† to the city, and no revenue from the grease or tankage.

*H. de B. Parsons, "The Disposal of Municipal Refuse."

†This price as stated is excessive, as the reclamation offset by the contractor in his bid must be noted.

"4. As the works are situated at some distance from the city, the haulage is only on garbage.

"5. When properly designed and carefully operated, the process need not be a nuisance, and its adoption adds a new manufacturing industry.

"DISADVANTAGES:

"1. The first cost is high. Expensive machinery and apparatus are required. The cost of renewals and repairs is large.

FIG. 160.—MAKING LAND WITH GARBAGE AT RIKER'S ISLAND, NEW YORK.

"2. The odors and smells that are apt to be given off, and the expense to prevent such an annoyance.

"3. The distant location of the plant from the city, in order that the odors may be least objectionable.

"4. Being a manufacturing plant, it should be erected and operated by private interests. Civic authorities often do not succeed in an economical management of business enterprises. Being operated for profit, there is danger that the works may create a nuisance.

"5. Requiring skilled labor, there is some danger of strikes.

"6. The garbage must be separately collected. There will always be some foreign material, tin cans and the like, which must be sorted at the works.

"7. There being but one plant, the system would be crippled by fire or by any cause stopping the plant. The plant cannot be divided, as small plants do not pay.

"8. The process cares for the garbage only, leaving the remaining refuse to be otherwise treated."

FIG. 161.—BELT CONVEYOR USED IN MAKING LAND WITH STREET REFUSE AT RIKER'S ISLAND, NEW YORK.

I submit this summary to the reader for his consideration without at all endorsing the statements it contains.

For aid in your consideration I submit the following facts:

The average cost to the city, under the contract, for haulage on scows and final disposition of the garbage at the present time in New York City is approximately 60 cents per ton.

Odors and smells are creating no nuisance and have been obviated by a simple addition of a high chimney or stack. In the city of Rochester, N. Y., the plant is located in approximately the center of the city.

The city of Cleveland is operating its own plant, and the authorities are satisfied with their investment.

The skilled labor is in no larger proportion to the whole number employed than in any plant which operates machinery.

"Acts of God and enemies of the King" have been recognized from time immemorial as necessary evils of any business.

Putrescible waste disposal is the end to which all efforts of waste disposal are at present being directed because of sanitary reasons.

CHAPTER XVII

Waste Disposal by Cremation, Incineration and Destruction.

EDWARD D. VERY, C.E.,
Sanitary Engineer, Department of Street Cleaning, New York City.

The general public opinion, led by the expressed convictions of physicians who desire only the sanitary results of waste disposal, is that municipal waste should be destroyed by fire. To attain this end many have attempted the design, construction and operation of devices variously known as crematories, incinerators and destructors. The dictionary defines cremation and destruction as about the same, *i.e.*, burning up or reducing to ashes by heat. Destruction is defined as putting out of existence. In general practice cremation applies to the burning of garbage only, incineration to the burning of light refuse and rubbish, and destruction to the burning of the mixed wastes.

The first plant to dispose of municipal wastes was installed in 1885. Since that time up to 1908 there were installed 208 devices in the United States, and the statistics show that 108 of these had been discontinued and 6 were awaiting trial. Up to the year 1908 the United States Patent Office had issued 210 patents for devices, of which, of course, many were improvements on former patented devices. The United States Census of 1905 gave statistics on inquiries made to 154 cities of over 30,000 inhabitants, which were summarized as follows: no report, 38; burning, 34; reducing, 20; other methods, 55.

The fact that this country had never made an attempt to solve this question prior to 1885 is rather startling in the face of the evident need of such solution in any civilized community. The fundamental difficulty is that the city fathers, who must initiate the work of improvement along these lines, do not appreciate the difficulties which are involved in the question, and have usually been satisfied with a covering up of the material on the "out of sight out of mind" plan. When the subject does come to a head, they consider that their order to "burn

it up" is an easy one to carry out. The engineer so ordered is a wizard whose education has put him in possession of knowledge of natural forces and mechanical control which permits him to perform impossible feats with ease. Then comes the man with the device who talks learnedly upon the subject, usually completely over the official head, and when he concludes by promising from 100 per cent. to 125 per cent. efficiency for his machine upon a guarantee, the day is won, the problem is solved, the money is provided and the duty has been performed. It may surprise many to know that this year, 1910, a city of 30,000 inhabitants in the State of New York has resolved to make the necessary improvement along this line and has appropriated the sum of $50.00 for the purpose of investigation. Again, one reads with wonder that a distinguished engineer in charge of the design of a large municipal destructing plant has proclaimed it the first and most efficient plant in the country, in the face of the fact that the fires have not been lit and its success or failure is not yet assured.

To design a plant one must know the theory of fuel consumption, the best methods of obtaining the full fuel value in combustion, the particular fuel to be used and the necessary results to be obtained; and then the question of performing the operation with due regard to economy must be added. In incineration, that is, the burning of light refuse and rubbish, this is not so difficult a proposition. An average sample of refuse and rubbish as received in New York City has been estimated to contain 60 per cent. of combustible material, with 11.5 per cent. of moisture. The calorific value is approximately 6,700 B. T. U. The burning of this material will be simple, provided the 28.5 per cent. of residue, which will form a slag, is taken care of. This proposition is elementary, and we utilitarians will agree that if a proper layout is made there may be a use made of the heat—but in designing the plant a full knowledge of the details is necessary. An incinerator properly designed for such work is now furnishing heat for the power to pump sewage in the Hamburg Canal trunk sewer in Buffalo, N. Y. An incinerator of this type which was designed to furnish the heat for generating power at the Williamsburg bridge in this city failed for the reason that it first did not provide for the taking

care of the slag which was formed from molten glass, crockery and dirt contained in the rubbish, and further because an experimental plant was immediately overloaded with the whole lighting project, for which it was not designed. In attempting to generate electricity for lighting purposes, it must be remembered that the material is usually collected in the daytime when artificial light is not necessary, and must be stored and rehandled; then, too, the maximum receipt of fuel is in the summer, when the light is needed for the shortest period of time, and

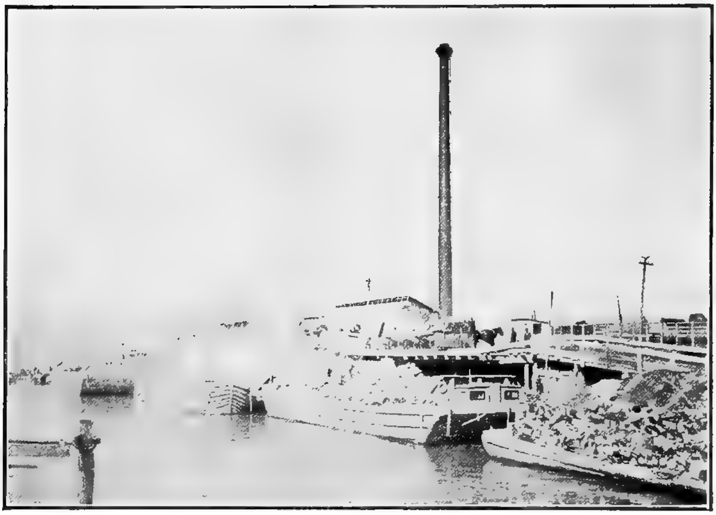

FIG. 162.—DUMP, SHOWING INCINERATOR, 47TH STREET, NEW YORK CITY.

the minimum is in the winter time, when the long hours call for the greatest amount of electric power. This material is very inflammable, and in order to get a steady heat there must be an arrangement for holding the combustion down to a reasonable rate. There should be no attempt to feed bulky materials to the furnace, which will cause an inrush of cold air, resulting in the cooling of the temperature. Feed should be made from the top through the smallest practicable orifice.

Crematories are the result of the need for some method of destroying putrescible, germ-breeding swill, and are the real dif-

ficult proposition. They are furnished with a wet fuel, and the demand for economical operation calls for a method of burning the material with the least amount of added fuel. It is necessary not only to drive off the moisture so as to be able to burn the residue, but it is also necessary to burn up the noxious gases or vapors which arise from the evaporation of the moisture. The general plan adopted has been a two-grate affair, in which the raw material is received on the upper grate to be dried by the heat which comes from the combustion in the lower grate, the dried product being afterwards raked onto the lower grate

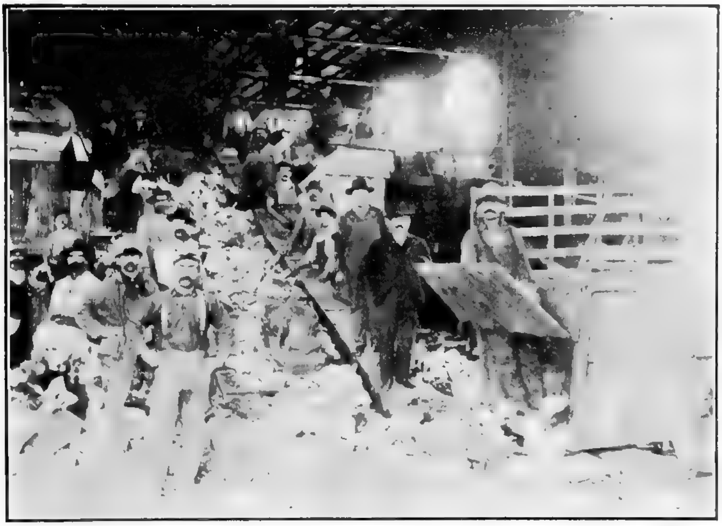

FIG. 163.—CONVEYOR AT INCINERATOR, NEW YORK.

to become the fuel to dry the next batch. Devices have been designed which so place the fire that it will pass over the material, causing evaporation, but afterwards pass under on the way to the stack, and in passing furnish heat for combustion. These last devices must be equipped with an auxiliary fire for the burning of the gases, and it is usual to place such auxiliary fires in the base of the stack, and so baffle the stack at the lower end as to cause the retardation of the outgo and the consequent thorough effect of the heat in consumption of the foul gas or vapor. In these devices air must be introduced for initial com-

bustion and also air to mix with the gases to permit of their combustion. If you have ever tried to burn up weeds or grass, you can appreciate the difficulties attending this cremation, for the mass must be opened up to permit of thorough effect, and then comes the smudge, which must be reduced to an innocuous smoke or vapor. Devices for stirring up this mass are difficult of design and practically impossible of operation. The result has usually been incomplete combustion, and the fact that un-

FIG. 164.—PICKING SALABLE MATERIAL FROM CONVEYOR AT INCINERATOR, NEW YORK.

consumed organic matter comes out with the ash undoubtedly condemns the system.

A crematory which had seemed satisfactory in other places was started in the Borough of the Bronx in this city, and after 36 hours' operation was closed down by the Board of Health. The probable reason was a failure to study the particular fuel which was to be consumed. Here then is the problem in crematories: to furnish heat to drive off the moisture, to burn the vapor or gas driven off, to give perfect combustion to the consuming of the fuel and to offset the loss of heat through radia-

tion. The heat to burn the gases will not be effective if less than 1,250° F.

Destructors have been in operation since 1876 in Great Britain, and today 250 muncipalities are operating them and 130 municipalities are using the heat from them in power, which is used in generation of electricity and in the pumping of water or sewage. This type has been studied by engineers in this country, and the latest and most up-to-date plant on this plan is now in operation in the Borough of Richmond (Staten

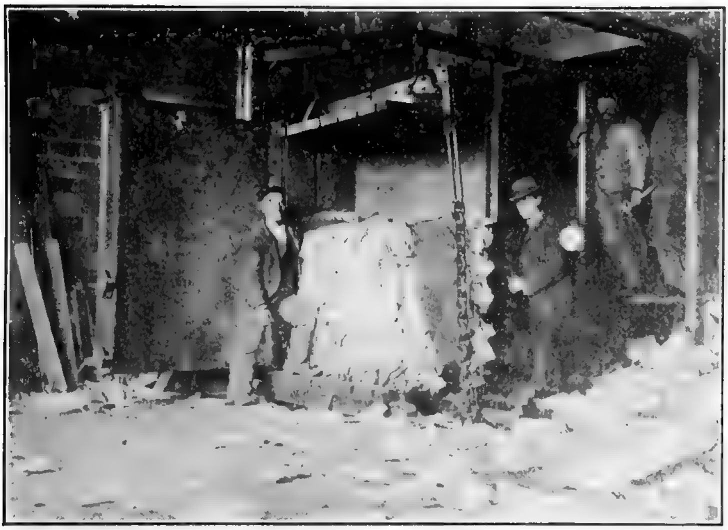

FIG. 165.—BALING PAPER AT INCINERATOR, NEW YORK.

Island) in this city. It is refreshing to note the sensible method adopted in the investigations made before the construction of this plant. The officer in charge of waste disposal in that borough was authorized to go to England and make a thorough investigation of the British refuse destructors in actual operation, and to note the composition, quantity and quality of the refuse destroyed, to particularly note the weak points of this method, and to obtain such data as were necessary to apply this plan to the conditions existing in Staten Island. Thirty-nine installations were inspected and complete data were obtained of the main factors of mixed refuse destruction. An analysis was

made, and comparative tables were made and analyzed. Mr. Fetherstone, in his published report, says: "In practice the destruction of refuse may be successfully attained by burning it by means of forced draught in a so-called Dutch oven or chamber where the brickwork is maintained at a high heat and the escaping gases are subjected to a high temperature for a sufficient length of time to oxidize the combustible constituents of the material.

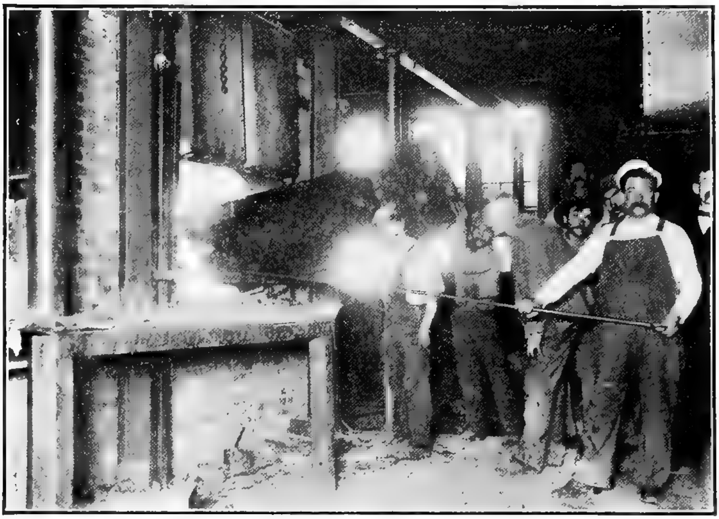

FIG. 166.—FEEDING AN OLD SOFA TO INCINERATOR. HEAT IS WASTED BY INTRODUCING SUCH LARGE OBJECTS.

"The aim in the design of refuse destructors should be to maintain a steady temperature. If it be considered that 1,250° F. is the minimum at which septic poisons in the products of combustion are destroyed, the higher limit of temperature is fixed by the materials used in the construction of the furnace. Temperatures between 1,250° F. and 2,000° F. are desirable both from an economic and a sanitary point of view."

The result of this investigation was that a general plan was drawn up and bids with specifications asked for in December, 1906, and the device adopted was of the Heenan-Froude type. This destructor consists of one unit of 60 tons capacity each 24

hours, containing four grates with divided ash pits, each grate served by one clinker cooling chamber. There is one 183 H. P. Babcock and Wilcox water tube-boiler without a coal grate, one air heater or regenerator, a fan for forced draught and ventilating ducts, etc. The carts dump the refuse into a bin at the rear of the furnace, whence it is shovelled by hand on to the grates. After the combustible material in the refuse is burned on the grate, a residue in the form of clinker or slag accumulates, which is removed at intervals depending on the amount

FIG. 167.—INCINERATOR IN COVERED DUMP IN BROOKLYN. TOP FEEDING. SMALLER ORIFICE IS BETTER.

of incombustible materials contained in the refuse. This clinker is withdrawn in a heated condition and drops through a trap door in the floor to the clinker cooling chamber immediately below the furnace. Air for combustion is forced through this heated slag and returned to the furnace to assist in drying the new charges of green refuse. This conserves the heat energy and the stokers do not have to wheel away the hot material. This clinker, when cooled, is wheeled out of the building. The gases from the burning refuse in the furnace pass over the successive grates, and are mixed and oxidized in a combustion chamber

before entering the boiler. After passing through the boiler the gases enter an air heater consisting of a number of pipes through which the gases pass and outside of which air for combustion in the furnace is forced by a centrifugal fan. From the heater the gases pass to the main flue and thence to the chimney. Provision is made for depositing the fine dust contained in the refuse and preventing its escape from the stack.

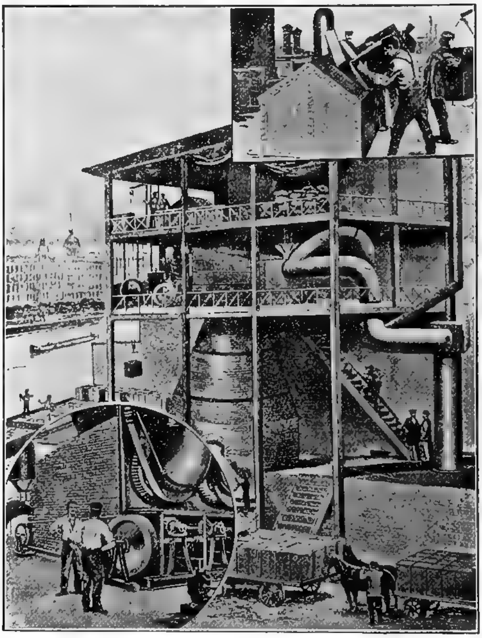

FIG. 168.—GARBAGE DISPOSAL PLANT, BERLIN.
(Courtesy of *Scientific American.*)

This device was accepted May 21, 1908, and has since been in operation; it is working satisfactorily, but some defects have been found, and the cost has been found to be rather larger than had been anticipated.

The plan for using this type of destructors is to use units of not over 100 tons' capacity in 24 hours, and to locate them in various sections of the municipality, to ensure economical haul. Their use is yet to be proven as the solution of the question, and it is probable that if they prove satisfactory in their

perfected state, they will be confined to cities of the second class or less.

To sum up, the knowledge on this subject is so limited as to demand a great deal of study yet before the requirements will be met, and if utilization of by-products is to be carried out, cities having large quantities of wastes will hesitate in adopting destruction. The advocates of destruction claim that the heat from the process may make power, but up to date such power has not been developed with any great degree of economy. The clinker they say may be used in making brick, tile, etc., but this has not yet been done.

I submit that when we pass through a furnace the large amount of inert matter contained in the ash we are doing a work of supererogation which is costly and of no value. In fact, I understand that up-to-date destructor men are considering the screening out of this material to relieve the heavy winter load. While crediting these men with the progress made of late, we still must ask that they show methods to overcome both mechanical and economic objections before they claim for their devices that degree of perfection which a sanitary disposal demands.

Those who are about to enter upon this line of work are fortunate in having the best and worst features of the subject before them, and it is hoped that they will give the subject a careful study in each individual case before proposing the solution of its difficult problems; and it is to be remembered that the device must be so designed that its operation will not depend too much upon the operator, but will accomplish the result rather in spite of him. No general statements are to be accepted. The statistics and sanitary axioms of agents for devices on the market are to be avoided. It is well to give credence to facts presented by the oldest inhabitant, but it does not follow that the municipality should make him the consulting engineer. For advice I would offer: "Keep inviolate the fundamental rules of fuel consumption. Don't let public sentiment lead your judgment. If not allowed to use your own best opinion, don't design."

CHAPTER XVIII

The Disposal of City Sewage.

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The city is the most interesting experiment of modern times; and like all Nature's successful ventures it is an experiment in organization. The analogy between the municipal and the human organism can be carried quite far before it becomes a false one. Along the arteries of travel are grouped the living units in their houses, as the individual masses of cell protoplasm are arranged along the course of the blood vessels. Each depends on the whole organism for the supply of its needs, and each contributes, if the organism be healthy, its own peculiar quota to the working of the whole. Food supply and water supply and air supply must be brought constantly to each cell. If the avenues of entrance are clogged the individuals starve. Of equal importance is the simultaneous removal of wastes. Protoplasm, in the single cell, or in the organism, is in a state of constant flux which constitutes its life. Food and oxygen must be taken in, and *pari passu* waste products are given off, more or less completely oxidized remnants of organic combustion. If these are not promptly removed they act as poisons to the organism which produced them. The result of deficient kidney action is well understood, and the toxic effect of the wastes in the alimentary canal occupies a central position in current medical research. The bird that fouls its own nest has become a person of proverbial reproach. Among human beings the improper disposal of excreta has proved a fertile source of disease and death, as in the case of the Spanish War, where one out of five of our volunteer soldiery suffered from typhoid fever, mainly from gross negligence in this regard. In the municipal organism the difficulty of waste disposal is met by the water carriage system, in which all wastes are carried off in a closed

system of pipes, diluted with a large volume of water. The ultimate question still remains, however, though shifted from the individual householder to the community. At the end of the main sewer is the combined filth of the whole city to be dealt with. Sewerage leads to the new problem of Sewage Disposal.

City Sewage is a far less offensive substance than might be imagined. To the sight it is simply a grayish liquid with fine flecks of suspended matter in it; to the smell it is inoffensive when fresh, having only a faint, musty odor. Analysis shows that the average American sewage contains less than one part in a thousand of solid matter, the rest being water. Of the solid matter half is of mineral nature, so that only a residuum of perhaps four-hundredths of one per cent. of organic matter requires special treatment. It is the vast volume of the sewage stream, however, which makes the problem such a serious one. For example, there are now discharged into New York harbor about 500 million gallons of sewage a day. This amount of liquid would fill the bed of a river ten feet deep and a hundred feet wide and thirteen miles long. Even four-hundredths of one per cent. of this immense mass of liquid amounts to 800 tons; and this is approximately the amount of organic matter discharged into New York harbor every day.

The organic matter in sewage, which is the principal source of embarrassment in its disposal, is made up for the most part of imperfectly oxidized unstable molecules, which may undergo one or the other of two different series of changes. First, it may decompose or putrefy in the absence of oxygen, with the production of offensive gaseous compounds, like hydrogen sulphide and the amines. Or, secondly, under the influence of oxygen, it may undergo another process that we call nitrification, a slow burning or combustion which converts the organic matter into nitrates, or other mineral substances, without the production of foul odors and in a wholly innocuous way. Organic matter must either putrefy or nitrify, and the aim of sewage treatment is to nitrify it. This involves the supply to the organic matter of one to three times its weight of oxygen, with the special conditions under which the oxygen and the organic matter will unite; and it constitutes a problem in municipal chemistry of no mean magnitude.

The most obvious way to dispose of sewage is to throw it into the nearest body of water. Before true sewers existed the natural drains discharged into the nearest watercourse, and when they became filled with polluting matter the same plan was followed. Sometimes this works well. If the volume of sewage discharged into a stream is sufficiently small, there may be enough oxygen to unite with the organic matter and enough organic life in the stream to effect the union. Under such conditions there results a self-purification of a very satisfactory type. For example, Weston estimates that the Mississippi River above New Orleans receives a billion and a half gallons of sewage a

FIG. 169.—CHICAGO DRAINAGE CANAL AT WILLOW SPRINGS. (Courtesy of R. R. McCormick.)

day, and yet is no more polluted than any surface stream. A striking instance of self-purification is offered by the case of the Chicago Drainage Canal, constructed to reverse the flow of the Chicago River and to carry the sewage of the city away from Lake Michigan, where it polluted the public water supply, and across the divide, through the Desplaines and Illinois Rivers, into the Mississippi. The sewage is primarily diluted with about ten times its own volume of lake water (3.3 cubic feet per second per 1,000 persons contributing sewage), and as one sails down this wonderful ditch, which is over thirty miles long and which cost sixty-five million dollars, there is almost nothing to indicate to the senses that it is not a river made by nature,

rather than by man. Analysis shows that at Wesley, 160 miles from Chicago, the chemical constituents of the Illinois River have been reduced to a value about the normal for an ordinary river water. Oxidation has done its work, as shown by the increase in nitrates, parallel to the diminution of organic matter. Mere dilution with purer water coming in from tributary streams or from the ground is, however, the principal factor; for there is a 90 per cent. decrease in chlorine, the amount of which is, of course, not affected by chemical and bacterial changes. The process as a whole is rightly known as Disposal by Dilution.

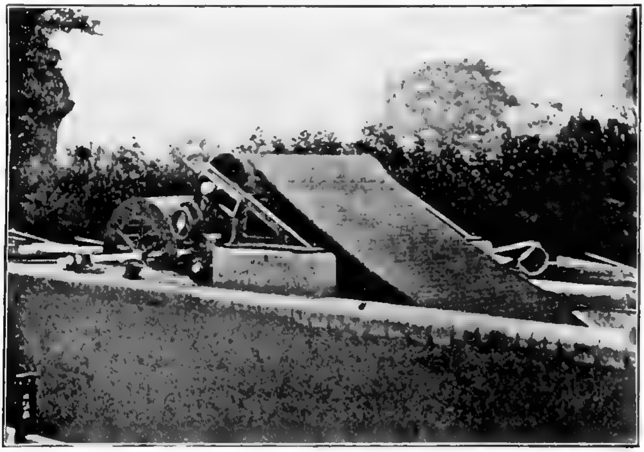

FIG. 170.—SEWAGE SCREEN AT BIRMINGHAM, ENGLAND.
(Copied, by permission, from Kinnicutt, Winslow & Pratt's *Sewage Disposal.*)

Disposal by dilution requires that there shall be a sufficient volume of diluting water, containing sufficient oxygen to maintain aerobic conditions and to keep nitrification under way. The whole process changes when the volume of sewage exceeds the maximum which may be absorbed by a given stream, which may be roughly stated as one part of sewage to fifty parts of water. When that limit is much exceeded or when the limit of available oxygen for the oxidation of organic matter is passed, then the conditions of putrefaction are set up. It is like Mr. Micawber's philosophy: "Annual income twenty pounds; annual expenditures nineteen pounds naught and six; result happiness. Annual

income twenty pounds; annual expenditures twenty pounds naught and six; result misery." Up to a certain point everything goes well, but beyond that point conditions are totally changed, and instead of a self-purifying stream you find a foul septic tank in which there is no true purification at all. Decomposable organic matter accumulates on the bottom, and the whole stream or pond is turned into a bubbling pool of putrefying sewage, the odor from which may produce an intolerable nuisance for long distances from its banks. Such conditions now exist within the limits of Greater New York in the estuaries of the Gowanus Canal and Newtown Creek. A classic example of stream pollution was furnished by the condition of the Seine below Paris, where, in 1876, eye-witnesses described the formation of sludge banks ten feet deep, from which gas bubbles rose, nearly three feet in diameter; and Dr. William Budd gives the following description of the Thames at London in 1858:

"For the first time in the history of man, the sewage of nearly three millions of people had been brought to seethe and ferment under a burning sun, in one vast open *cloaca* lying in their midst.

"The result we all know. Stench so foul, we may well believe, had never before ascended to pollute this lower air. Never before, at least, had a stink risen to the hight of an historic event. Even ancient fable failed to furnish figures adequate to convey a conception of its thrice Augean foulness. For many weeks the atmosphere of Parliamentary Committee-rooms was only rendered barely tolerable by the suspension before every window of blinds saturated with chloride of lime, and by the lavish use of this and other disinfectants. More than once, in spite of similar precautions, the law-courts were suddenly broken up by an insupportable invasion of the noxious vapor. The river steamers lost their accustomed traffic, and travelers, pressed for time, often made a circuit of many miles rather than cross one of the city bridges.

"For months together, the topic almost monopolized the public prints. Day after day, week after week, the *Times* teemed with letters, filled with complaint, prophetic of calamity, or suggesting remedies. Here and there, a more than com-

monly passionate appeal showed how intensely the evil was felt by those who were condemned to dwell on the Stygian banks. At home and abroad, the state of the chief river was felt to be a national reproach. 'India is in revolt, and the Thames stinks,' were the two great facts coupled together by a distinguished foreign writer, to mark the climax of a national humiliation."

The success of disposal by dilution depends, then, upon the relation between the volume of the sewage and the volume of the body of water into which it is discharged. With small streams and lakes it is likely to fail; with large rivers and large tidal estuaries it may often prove successful. The concentration of population and the rise in sanitary standards tend more and more, however, to limit the field for this method of disposal. Even in the case of New York, whose insular position is adapted in an unique degree to disposal by dilution, it threatens soon to prove inadequate, and the Metropolitan Sewerage Commission in its recent report states that the water in the main channels of the harbor above the Narrows, and also in both the East and Hudson rivers, "is more polluted than considerations of public health and welfare should allow," and that "the digestive capacity of this water for sewage is so reduced by pollution that restrictions should at once be placed upon the discharge of sewage therein to prevent the harbor from becoming positively offensive."

In England almost all the large cities have been forced by the aggravation of such conditions as these into a deliberate policy of sewage purification; and the same conditions are now operating in the United States. How far it is necessary to carry the process depends, however, on local conditions. Sometimes it is well to convert all or nearly all the organic matter into the mineral form and to effect a substantial reduction in bacteria. Sometimes it is only needful to strain out the grosser polluting materials and to discharge the liquid sewage untreated; and there are all grades of exigency between.

The first problem in almost every case is the elimination of the coarser floating particles by some form of straining or screening. This is at present one of the most interesting points in the whole field of sewage treatment. Until two years ago we were content in America to screen very roughly with bar

screens, half an inch or an inch apart. This took out the large fragments of paper and garbage, the sticks and corks and the like, but let all the finer material through. In England, and particularly in Germany, finer screens of wire cloth, with meshes as close as a tenth or a twenty-fifth of an inch apart, have long been used; and much ingenuity has been devoted to the design of these screens and of movable devices by which they can be automatically cleaned. At last American engineers have awakened to the possibilities of this method of treatment. At Reading, Pa., there is now in operation one of the most inter-

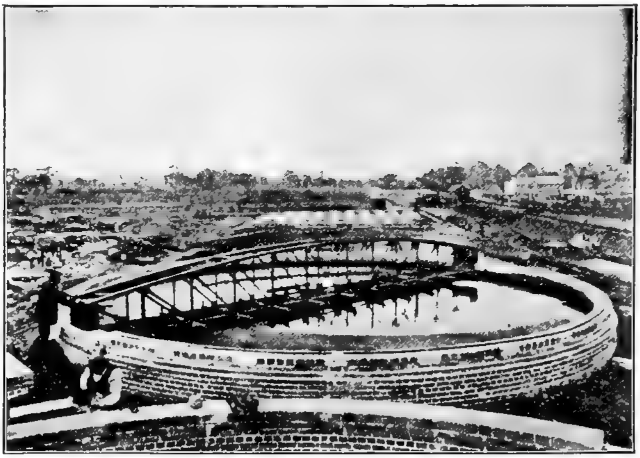

FIG. 171.—SEDIMENTATION TANK AT BIRMINGHAM, ENGLAND.
(Courtesy of John D. Watson.)

esting mechanical screens in the world. It is a cylinder of wire cloth, having 40 meshes to the inch, through which the sewage drops, and to one end of which the screenings are forced by a worm conveyor. A fine screen of this sort will remove 40 cubic feet of screenings from a million gallons of sewage, while the coarse bar screens hitherto in use take out only 3 or 4 cubic feet. There is undoubtedly a great future for fine screening in this country. In Germany, Cologne and many other cities find that careful screening is the only treatment necessary before discharge into large rivers; and it is likely that the New York harbor problem can be much simplified by a judicious application of this method.

Where it is necessary to remove a larger proportion of suspended solids than can be held back by screening, sedimentation is the next process called into play. Screening alone is sufficient for all practical purposes in some cases, so in others screening and sedimentation will produce an effluent pure enough to be discharged into adjoining waters. As a preliminary to the processes used for final purification, sedimentation almost always plays a part, for the suspended solids offer one of the most difficult problems in the whole art of sewage disposal, and

FIG. 172.—CLICHY, NEAR PARIS.—SETTLING BASIS FOR THE SEWAGE OF PARIS.
Sand and other heavy, coarse matters settle, and are screened here. The basin is constantly dredged. The material excavated is deposited in barges, and carried to the country and spread upon land.

it is generally more economical to remove them by preliminary treatment, rather than to allow them to pass to the surface of the filter beds.

The purifying action of a sedimentation tank depends, of course, solely on the physical factors of velocity and time. If the dimensions of the tank are such that the flow is reduced only to a rate of 30 feet per minute, the heavy mineral matter,

gravel, sand and the like, will be removed, but the finer organic particles will not be affected. Such a tank as this is known as a Detritus Tank or Grit Chamber, and forms a part of practically all sewage works, generally in intimate connection with the screening process. True sedimentation of organic solids, on the other hand, requires a velocity as low as 6 feet per minute or less, maintained for a period of several hours.

In general, the tanks used for sedimentation are rectangular basins of concrete or masonry, with a capacity of 4 to 12 hours flow of sewage. Taking the shorter period, the sewage from 100 persons, assuming the reasonable value of 100 gallons per capita per day, would require a tank holding 1,600 gallons, say 4 feet wide and 4 feet deep and 13 feet long. In place of shallow basins of this ordinary pattern, English engineers, notably at the city of Birmingham, have obtained very satisfactory results by the use of deep tanks with conical or pyramidal bottoms. The sewage enters near the bottom, and as it rises and spreads out in the conical section, progressively diminishes in velocity and leaves its suspended solid matter behind, so that the effluent flows off clear at the top. These deep tanks have the advantage that the heavy sludge can be drawn off by a valve at the bottom without emptying out the liquid above.

Where still more complete removal of suspended solids seems to be called for, the force of gravity may be re-enforced by the addition of chemicals which produce a flocculent precipitate, capable of carrying down with it the finer particles, even to some of those which exist in a state of colloidal suspension. This process of chemical precipitation constitutes one of the most interesting chapters in the history of sewage purification. It was originally believed that sewage sludge contained elements of considerable manurial or other economic value, and chemical precipitation was developed, not only as a method of sewage purification, but as a source of possible commercial profit. Between 1856 and 1876 no less than 417 patents were issued in England covering devices connected with this process. Today these golden dreams seem to have vanished; and all we hope to do is to minimize as far as possible the heavy costs of sewage treatment.

After years of experimentation with all sorts of likely and unlikely substances the conclusion was reached that ferrous sulphate (copperas) and lime constituted the most favorable chemicals for precipitation. When added in the proportion of approximately 56 parts per million of lime and 14 parts of copperas, a flocculent precipitate of ferrous hydroxide is produced, and in the subsequent process of sedimentation there ensues a very complete removal of suspended matter. This is unquestionably the most efficient of all processes for eliminating solids. It is a costly one, however, first on account of the chemicals involved and second on account of the large volume of sludge produced. The semi-solid residue removed from the precipitation tanks amounts to 20-40 tons per million gallons of sewage treated, and this must be pressed and burned or dug into the ground. Of late years it has been the tendency to abandon the whole process of chemical precipitation on account of its high cost, and Worcester, Mass., and Providence, R. I., are the only large cities in which it is now in use in the United States. Where for any special reason very complete solid removal is, however, desired, chemical precipitation is well worthy of consideration; and in cities whose sewage receives industrial wastes already containing iron salts (as is the case at Worcester), the cost of operation may be somewhat reduced.

The problem of sludge disposal is a serious one in connection with plain sedimentation processes of solid removal, although it is not quite so onerous as in the case of chemical precipitation. At the least there is produced some 5 to 10 tons of wet sludge (containing 90 per cent. of moisture) for every million gallons of sewage treated. For a community of 100 persons (assuming 100 gallons of sewage per capita) this would mean one to two hundred pounds of wet sludge a day. With a village of 100 persons it would be easy to deal with this semi-solid waste by burying it; but when you come to a city of 100,000 inhabitants and must dispose of 50 to 100 tons a day, the task is far from simple. As a matter of fact, this is still a problem which awaits satisfactory solution. Cities on the seacoast can carry their sewage sludge out to sea in tank steamers and dump it in deep water with reasonable success and economy. For inland communities there remain only the alternatives of burying

or burning, both of which are costly and unsatisfactory. Utilization seems theoretically promising, as it did in 1860; but it has not been practically realized except with sewages like that of Bradford, England, which contain an enormous proportion of fats from industrial sources.

There is one form of the process of sedimentation which is specially designed to minimize the sludge problem and which, to a limited extent, does achieve that end. This is the septic tank, associated particularly with the work of Cameron, but in its essential features dating far beyond the year 1895, when he gave it that picturesque name. The septic tank is indeed only a sedimentation basin in which the suspended solids are removed by physical processes, but in which they are afterwards allowed to remain, so that they may be partially decomposed and reduced to the liquid form by the action of putrefactive bacteria.

A septic tank is a sort of glorified cesspool, and for years it has been known that sewage matter stored in such a receptacle tended to disintegrate and pass into the liquid form. In France an overflow cesspool of this type was introduced by Mouras about 1860, and was patented in 1882. Professor A. N. Talbot, of the University of Illinois, built what were practically septic tanks at Urbana and Champaign in 1894 and 1895, and there were many other anticipations of the Cameron process; yet it was Donald Cameron's tank at Exeter, England, which first called wide attention to the practical possibilities of the process.

The first septic tanks were tightly closed, in the opinion that this was essential to the desired liquefaction. It has since been found, however, that this is wholly unnecessary. All that is essential is that the sewage, or the sludge removed from the sewage, should be retained in a stagnant condition; the bacteria growing in the liquid consume oxygen much faster than it can be absorbed from the surface, and anærobic conditions are easily maintained. In such a still pool of sewage sludge the putrefactive bacteria effect a hydrolytic cleavage of the organic compounds and ultimately split them up into such simple forms as nitrogen, hydrogen, carbon dioxide and marsh gas. The bacteria at work are of many kinds, and the changes are complex. The end products, however, are, first, the gases just mentioned; second, soluble substances like ammonia, undecomposed amido-bodies and

fatty acids; and third, a solid residuum of stable peaty organic matter. The whole reaction is an exothermic one, evolving about 8 per cent. as much heat as energy as is left in the final products.

There are only two important structural differences between a septic tank and a plain sedimentation tank. The first point is that the septic tank is larger, having, as a rule, a capacity of 8 or 12 or 24 hours' flow, instead of perhaps 4 hours. The second point is that special care is taken that the sewage shall enter and leave the tank by submerged inlets and outlets, so arranged as not to disturb the sludge and scum any more than necessary. In other respects the septic tank is simply a brick or masonry basin, covered perhaps with a wooden roof to protect it from the wind, but with no special features to distinguish it from any other tank. If in operation the sludge is removed at frequent intervals, the tank is merely a sedimentation basin. If it is allowed to remain, the liquid becomes dark colored, bubbles rise from the bottom and burst at the top, and sometimes a thick crust or scum forms over the whole surface. The amount of gas evolved is large, four or five gallons from a hundred gallons of sewage, and with closed tanks it is possible to collect this gas and burn it.

The net practical result of the septic process is an appreciable reduction in the amount of stored suspended solids, which at Birmingham, where the sewage contains bactericidal industrial wastes, amount only to 10 per cent. and at other places under favorable conditions reach 33 per cent. In general, perhaps a quarter of the suspended solids is thus reduced, a result which falls far short of what earlier workers claimed, but still a substantial gain in dealing with the sludge problem. Furthermore, septic sludge is more compact and thus easier to handle. It may contain only 80 or 85 per cent. of water, while sedimentation sludge contains 90 or 95 per cent., which means a volume only half as great in the former case as in the latter. Taking all things into account, the septic tank seems the most generally useful of all processes for the preliminary removal of solids, although both plain sedimentation and chemical precipitation find their places in the solution of particular local problems.

All the processes we have so far been considering are preliminary processes only, which remove from the sewage a larger

or smaller proportion of its burden of suspended solids, but which do not attempt complete purification of all organic matter, whether in solution or suspension. In disposal by dilution the self-purifying agencies of the stream ultimately bring about a true purification, an oxidation of the organic elements to stable mineral form. If no large body of water is available, these oxidizing processes must be carried out in the plant itself; and this constitutes the real and essential problem of sewage purification.

The most obvious alternative to the discharge of sewage into water is distribution over the surface of suitable land; and this process of Broad Irrigation is really the primitive form from which our modern modes of sewage treatment are derived. Under proper conditions the living earth readily absorbs and digests the foreign materials by the same processes which lead to the annual disappearance of manure from heavily fertilized land; and the organic matter is not only rendered harmless, but is changed into a form in which it serves as food material for the higher plants.

Baldwin Latham, the distinguished English engineer, believed that he had discovered sewers and irrigation areas in the ancient city of Jerusalem; and in China excreta have been utilized for centuries as fertilizer for the fields. At Lausanne in Switzerland, at Milan in Italy, at Bunzlau in Prussia, irrigation was practiced in the fifteenth and sixteenth centuries. The extensive development of the art dated, however, from the wave of sanitary reform which swept over England as a result of the Report of the Health of Towns Commission in 1844. This report marked the beginning of extensive sewerage construction in the modern sense, and, with sewerage, sewage disposal was urgently required. The Sewage of Towns Commission, which reported in 1858, after a careful study of available information, concluded that "the right way to dispose of town sewage is to apply it continuously to land, and it is only by such application that the pollution of rivers can be avoided." With the desire to dispose of polluting material, there grew up in these early days a parallel interest in the possible profit to be derived from crops grown on the irrigated land. The two aims are well balanced in the definition of sewage farming as "the distribution of sewage over a large surface of ordinary agricultural land, having in

view a maximum growth of vegetation (consistent with due purification)."

Progress in England along these lines was rapid, so that over two hundred irrigation areas of various sizes were in operation by 1883. Many are still in use today, and on the continent Paris and Berlin offer classic examples of this method of disposal. The Paris sewage is distributed on private land, and it is not easy to form a sound judgment as to the success of the system. The Berlin farms, on the other hand, are operated by the city and offer an excellent example of sewage farming at its maximum of efficiency. The farms include 39,000 acres of excellent sandy soil, an area of over 60 square miles. Grass and cereals, potatoes and beets are cultivated, and dairies and distilleries are maintained for the utilization of the crops. Even the effluent drains are stocked with fish. The farms are operated by convict labor, and with German intelligence and German military discipline the enterprise is not only successful as sewage disposal, but economically profitable, for the crops cover all costs of operation and pay for a part of the interest charges on the land.

In general, however, the results of broad irrigation have been by no means so favorable. The process requires large areas of land. The sewage of the community of 100 persons we have been considering as a unit would need from one to two acres; and the soil must be loose and sandy in character. Where, as in many English towns, the attempt is made to treat sewage on clayey soil, disaster is almost sure to follow. The land clogs and becomes "sewage sick," a local nuisance is created, and more or less unpurified sewage must be discharged into the nearest watercourse. Where local conditions and administrative efficiency are less favorable than at Berlin, the economic advantage disappears. The most recent studies of the British Royal Commission indicate that cropping of irrigated land scarcely pays for itself—still less contributes toward the cost of sewage treatment. In the arid regions of the western part of the United States, where every drop of water, as such, is precious, and where the manurial value of sewage is re-enforced by its water value, sewage farming becomes really profitable. In many parts of California and Colorado and other western States, irriga-

tion is clearly indicated as the best method of sewage treatment. Elsewhere, however, its application is more than problematical. The idea of converting the wastes of a city into walnut groves and fields of waving corn is an attractive one. The engineer, however, always wants to know the cost; and here, as in other modes of sewage utilization, it is poor policy to recover valuable elements that cost more than their intrinsic value to recover.

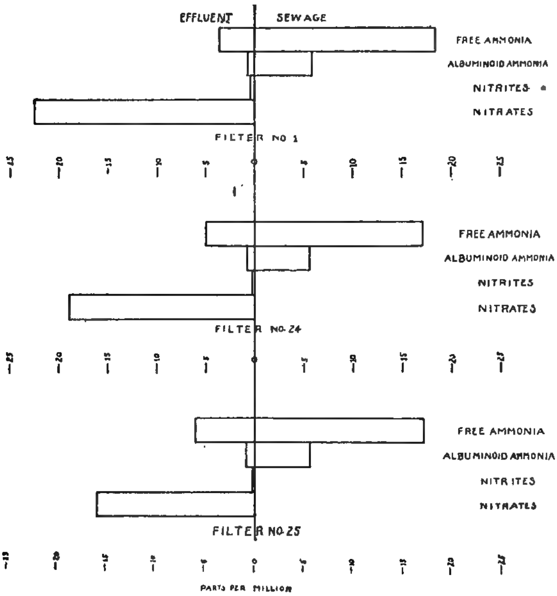

FIG. 173.—NITROGEN CHANGES IN INTERMITTENT FILTRATION.
(Copied, by permission, from Water-Supply Paper No. 185, U. S. Geological Survey.)

The real art of sewage disposal began only when the crude process of broad irrigation was freed from the seductive hope of agricultural gain, and developed intensively and scientifically as a means for sewage disposal, pure and simple. This was the work of the Massachusetts State Board of Health; and it is one of the chief prides of American sanitarians that all the modern processes of sewage treatment owe their first inception to the work carried out in the little testing station established in 1887 on the banks of the Merrimac River.

German and French investigators had shown that living micro-organisms were concerned in the processes of purification that went on in the soil of an irrigation field. The English chemist, Sir Edward Frankland, proved in 1870 that sewage could be purified in gravel filters at much higher rates if it were applied intermittently with alternate rests for absorption of the oxygen needed for nitrification. It was in the Massachusetts work, however, that all the facts were brought together so as to make it clear that the essentials for successful sewage treatment were three: a bed of sand or gravel particles to support the growth of bacterial colonies, the passage of sewage in thin films over these organic growths, and a supply of oxygen with which the bacteria could oxidize the organic substances. The Massachusetts experiments showed that these ends could be reached by applying the sewage in regulated intermittent doses. The rate of filtration could thus be raised from 5,000 or 10,000 gallons per acre per day (for broad irrigation) to 50,000 or 100,000 gallons. Our population of 100 persons would require only 4,000 square feet instead of 40,000. This process of Intermittent Filtration was at bottom irrigation still; but it was irrigation made scientific and intensive.

In the process of intermittent filtration, the organic matter is converted to a very large extent into soluble mineral form, and passes off in the effluent as a nitrate salt. Thus the experimental sand filter at the Sewage Experiment Station of the Massachusetts Institute of Technology at Boston has given the following average results for the last six months: It is an outdoor bed 400 square feet in area receiving septic sewage at a rate of 400,000 gallons per acre per day, and, as shown by the table, the unstable organic compounds, indicated by the free ammonia, are very largely converted to the nitrate form.

PURIFICATION EFFECTED BY INTERMITTENT FILTER.

Parts per million.

	Total Organic Nitrogen.	Free Ammonia.	Nitrogen as Nitrites.	Nitrogen as Nitrates.
Sewage	7.5	13.2	.1	.2
Effluent	6.1	4.2	.2	14.7

The active agents in this process are two distinct groups of bacteria, one of which changes ammonia to nitrites, while the

other further oxidizes the nitrites to nitrates. A sewage filter is a device for cultivating these nitrosomonas and nitrobacter organisms under the conditions most favorable to their maximum activity.

The construction of intermittent filters in regions like the northeastern part of the United States is extremely simple. This part of the country is covered with deposits of glacial drift sand, ideal in character for sewage purification. All that is necessary is to expose and level off areas of this sand, to lay lines of underdrains a few feet below the surface to carry off the effluent, and to install devices for discharging the sewage on the surface. A bed may be dosed on one day out of three, or in smaller portions several times a day. In winter the beds are furrowed so that an ice roof forms on the top of the ridges while the sewage finds its way along the furrows between, and, though less efficient in winter than in summer, the microbes do their work at all seasons well enough for practical purposes. The effluent from an intermittent filter, properly built and carefully operated, is a clear liquid, colorless or slightly yellowish in color, with no odor or only a slightly musty one, practically free from putrescible organic matter and low in bacteria—a liquid that can be discharged with impunity into even the smallest watercourse.

All this, of course, costs money. The land must be purchased and laid out; and the beds require more or less constant attention. Solid matter accumulates on the surface in the form of a dry crusty sludge, and this must be removed two or three times a year, while between whiles the bed may require raking over to keep its surface in good condition. A fair estimate of the cost of operating an intermittent filter area would probably be in the neighborhood of $15 per million gallons of sewage treated, which would amount to fifty cents per capita per year. This is, on the whole, however, a cheap solution of the difficulty, and in regions where there is plenty of suitable sand it has proved eminently satisfactory. There are today 28 plants of this type operating in the State of Massachusetts alone.

The successful and economical use of the process of intermittent filtration is limited to those regions where ample areas of the right soil are easily available. In clayey or chalky regions

sand beds must be artificially constructed with material brought from a distance; and this would make the cost of the Massachusetts method almost prohibitive. It was in England that the problem pressed hardest for solution, and in England were devised the newer methods of treatment which are sometimes called "biological processes." They are no more and no less biological than intermittent filtration. The same forces are at work, the oxidation of organic matter by bacteria, only that the processes are still more intelligently and intensively controlled.

FIG. 174.—INTERMITTENT FILTER BED AT LAKE FOREST, ILL. (Courtesy of J. A. Alvord.)

Mr. W. J. Dibdin, chemist to the London County Council, was one of the first to attempt to modify the sewage filter so that it would operate at higher rates, and as a first step he naturally sought to build his beds of coarser material. In a notable series of experiments at the Barking outfall on the Thames, he found that purification could be effected in beds of coke if only the sewage were held in contact with the material, instead of being allowed to stream directly through. In sand filters, frictional resistance delays the passage of the sewage, so that time is given for the purifying process. With coarser materials, however, it is necessary to regulate the flow by making the beds water-tight and retaining the sewage in them until puri-

fication is completed. This was in outline the genesis of the contact bed.

Beds of this type are then simply concrete or masonry basins filled with crushed stone or coke or slag in which sewage is allowed to stand for a period of about two hours. After one dose is withdrawn, the beds stand empty for aeration for four hours or so and another dose is then introduced, three fillings a day being perhaps an average. In the standing-full period, the bacterial films on the stones absorb a large proportion of both suspended and dissolved solids. During the empty period there is nitrification, like that which goes on in the sand filter. In the succeeding full period there is a new action peculiar to the contact bed, in which anærobic bacteria hydrolyze certain of the organic substances with the production of amines and similar bodies, and the amines react with the nitrites produced in the empty period so as to set free nitrogen in the gaseous form. There is a peculiar sewage disposal problem at Belfast, Ireland, due to the enormous growths of Ulva, the green sea-lettuce, on the polluted foreshores. Ordinary processes of sewage treatment would not solve this difficulty, for nitric nitrogen would foster green growths, much as ammonia would. The contact bed, with its actual elimination of nitrogen into the atmosphere, promises to meet even these special requirements.

A single contact treatment does not commonly yield an effluent sufficiently stable to discharge into a small stream. It is the general practice, therefore, to use double contact, treating the sewage first in a bed of coarse stone, perhaps 1½ to 2 inches in diameter, and then in a fine bed of perhaps half-inch material. The rate of treatment, even so, however, is much higher than that commonly used with sand beds, 500,000 gallons per acre per day against 100,000. For our group of 100 persons the necessary area would be cut again from 4,000 square feet to 800. The effluent even from double contact is less highly purified than an intermittent filter effluent. It is dark and somewhat turbid, but it should be free from the tendency to putrefactive decomposition.

The worst difficulty with the contact method is that there is considerable stoppage or clogging of the beds, due to settling, due to breaking down of the material, due to the growth of organisms

in the bed, and partly to the deposition of solid mineral matter in its interior. Stoppage due to breaking down may, of course, be controlled somewhat by using hard material. Stoppage due to the growth of organisms can be checked to a considerable extent by proper resting of the beds. The loss of capacity or clogging due to the deposition of mineral matter is more serious, and with many sewages appears to necessitate the renewal of the beds at intervals. After five years in such English plants as that at Manchester, it has been found that the beds must all be dug over and refilled.

Meanwhile, the problem of purifying sewage at high rates was being attacked in another and even more promising manner. The fundamental combination of bacterial films, sewage and air can be effected in various ways. The late Colonel George E. Waring attempted it at Newport in 1894 by blowing air into a bed of coarse stone below while sewage ran down through it from above. Theoretically this seems a satisfactory process, but it has not yet been demonstrated that a sufficient supply of oxygen can be economically supplied in this manner. Success was finally reached along another line by resorting to the device of applying sewage, not in bulk, but in a fine spray distributed as evenly as possible over the surface of the bed. By this means the rapid flow of large streams of sewage is prevented, and the liquid trickles in thin films over the surfaces of the filling material, while the spaces between are continually filled with air, the oxygen content of which in practice does not become seriously exhausted. The condition is analogous to that which obtains in the process of vinegar manufacture, when alcoholic liquor is allowed to run over shavings covered with growths of acetic acid bacteria. Under the name of the trickling, or sprinkling, or percolating bed, this has come to be considered one of the most promising and effective of all devices for sewage purification.

As in the case of contact beds, almost any hard non-friable material may be used for the construction of trickling filters. In America the size of the filling material is generally between 1 and 4 inches, and the depth of the beds between 5 and 6 feet. Mr. Rudolph Hering, in a very enlightening review of the underlying principles of sewage treatment, has recently pointed out

that there are three fundamental variables in this process of purification: air supply, total area of bacterial films, and time of exposure. The area of bacterial films is conditioned by the size of the filling material and the depth of the bed (the smallest material, of course, giving the greatest surface), and the time of exposure is controlled by the rate at which sewage is applied. Reduced to its lowest terms, a trickling filter is simply a heap of stone or other material of such size, depth and texture as to support a bacterial growth sufficient for the work in hand.

The distribution of the sewage over the surface constitutes the most serious difficulty in the construction and operation of the trickling bed. In England, many of the disposal areas are equipped with mechanical distributors of great complexity. Some are designed on the principle of the lawn sprinkler and are revolved by the propulsive force of the sewage as it is discharged. Others are in the form of great movable weirs, which pass back and forth on rectangular beds, dripping sewage as they go. At Hanley a mechanical distributor was installed for a quarter acre bed which weighed 12 tons and wore out a 45-pound bridge rail in two years and a half.

At other English plants, like the most famous of all, at Birmingham, and at most American disposal areas, the sewage is distributed by spraying it upward from fixed sprinkler nozzles. This method effects a less perfect distribution than that attained by the English mechanical apparatus, but the cost of construction and renewal is very much less. Improvements are constantly being made in the design of sprinkler nozzles and in the special devices used in connection with the operation. A modified form of fixed distributor devised at the Massachusetts Institute of Technology, in which the sewage is discharged down on to a concave cup, from which it splashes upward and outward, has also promise of usefulness; and this device is being installed at the new disposal plant now under construction at Mt. Vernon, N. Y.

The trickling filter can be operated at a rate of 2,000,000 gallons per acre per day, or four times as fast as the contact bed. For each person contributing sewage, only 2 square feet of surface are required, against 8 feet for the contact bed, 40 feet for the intermittent filter, and 400 feet for the irrigation

area. Furthermore, it is practically free from the clogging which menaces the permanency of the contact process, for the suspended matter comes through the trickling bed in the long run in about the same amount in which it goes on at the top, changed only in its chemical nature. The effluent is far less well purified than that of a sand filter. It is more turbid even than a contact effluent, and in appearance may not een seem very different from untreated sewage. The essential changes have, however, been brought about. The more unstable organic bodies have been oxidized and the effluent contains a sufficient excess of oxygen, so that succeeding changes will be nitrifications and not putrefactions. At Birmingham, England, where the trickling process has been most ably and exhaustively studied, a sewage flow of 30 million gallons a day is treated first in sedimentation and septic tanks and then on trickling beds having a total area of about 30 acres; and in discharging an injunction granted against the city by a lower court the Master of the Rolls has recently decided that the effluent from the Birmingham works actually improves the character of the river into which it is discharged. The large plants recently constructed in the United States at Columbus, Ohio (20 million gallons), and at Washington (1 million gallons), and Reading, Pa. (2 million gallons), are of the trickling type. The trickling filter is indeed an ideal mechanism for solving the essential problem of sewage disposal, the oxidation of organic matter. It exhibits the simplicity of all scientific applications, which are merely intelligent intensifications of natural processes. A pile of stones on which bacterial growth may gather, and a regulated supply of air and sewage, are the only desiderata. We meet the conditions resulting from an abnormal aggregation of human life in the city by setting up a second city of microbes. The dangerous organic waste material produced in the city of human habitations is carried out to the city of microbes on their hills of rock, and we rely on them to turn it over into a harmless mineral form.

So far we have said nothing about the problem of bacterial removal. In general, this is indeed a subsidiary question in sewage purification. Nine times out of ten the elimination of offensive organic decomposition is all that is necessary, and bacteria can be allowed to pass with the effluent into the stream to

be removed by the quite distinct processes of water purification from any water taken out for human consumption. Sand filtration effects a very considerable purification in living and lifeless constituents alike; but the contact and trickling beds are essentially oxidizing mechanisms without filtering action adequate for the removal of micro-organisms. It is true that in the unfavorable environment of the septic tank and trickling filter many sewage organisms do die out, but their elimination is incomplete and uncertain. If a nearly germ-free effluent is required, some special method must be adopted for bacterial removal. This particular problem has come into great importance of late in connection with the protection of shellfish industries, menaced by the sewage of seaboard cities. Fortunately there has been

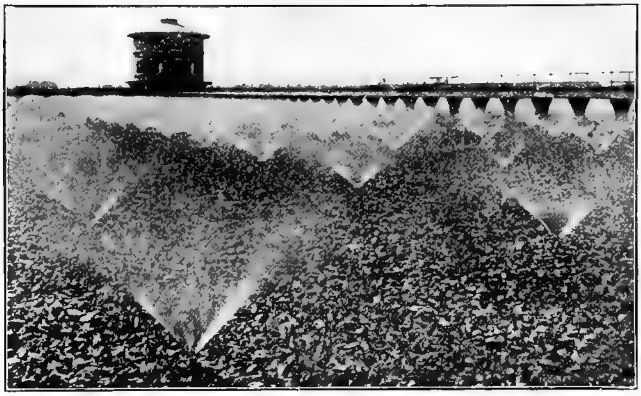

FIG. 175.—COLUMBUS TRICKLING FILTER IN OPERATION.
(Courtesy of J. H. Gregory.)

worked out to meet this need a simple and efficient method, a new chemical treatment, not designed, as in the old precipitation processes, to remove suspended solids, but merely to destroy the living germs. The application of ordinary bleaching powder, or chloride of lime, in small doses of 15 to 30 parts of bleaching powder to a million parts of sewage, will effect a satisfactory reduction of bacteria at a very reasonable cost, as shown first by Mr. S. Rideal in England and by Professor E. B. Phelps in this country. Baltimore, Md., has adopted this procedure, as have certain small towns on the New Jersey coast; and it promises to be of use in dealing with certain phases of the New York harbor problems.

There are many questions still to be solved in the purification of sewage. The removal of suspended matter, for example, urgently demands careful study; yet the work of the last ten years in England and the United States has blocked out the main outlines of satisfactory sewage disposal practice. The engineer can today successfully meet any demand for the purification of domestic sewage; and this purification may be carried to any degree of perfection for which the community in question is prepared to pay. If a clear and sparkling effluent, highly purified bacterially, is desired, he can design an intermittent filter for that purpose. If merely a stable effluent which may be discharged into a stream without creating a nuisance is wanted, he can build a trickling filter. If, on the other hand, a disinfected but not organically purified effluent is called for, that end, too, may be attained.

The actual practice of sewage disposal still lags far behind its theoretical possibilities. Mr. George W. Fuller, in an exhaustive review of existing conditions in 1905, found that out of 1,524 cities and towns in the United States with a population over 3,000, 1,100 had sewerage systems, while only 90 had constructed purification works. Among these 90 plants were 14 sewage farms, 41 intermittent sand filters, 13 chemical precipitation works, 29 septic tanks and 10 rapid filters of coarse materials. The vast majority of the communities, however, still discharged untreated sewage into the nearest watercourse. Of a population of some 28 million persons connected with sewerage systems, Mr. Fuller estimated that the sewage of 20,400,000 was discharged into fresh water and of 6,500,000 into the sea.

Within the last five years there has begun a notable sanitary awakening; but most of the work of municipal housecleaning still remains to be done. Engineers, sanitarians, chemists and bacteriologists must co-operate in doing it.

CHAPTER XIX

Making Illuminating Gas.*

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It is hardly necessary to call attention to the importance of the illuminating gas industry, further than to say that in a city like Greater New York there are employed about eight thousand men to do this kind of manufacturing. This would mean there are about forty thousand people directly dependent upon the gas industry for their subsistence. The works that produce gas in Greater New York are capable of sending out from one hundred and thirty to one hundred and forty millions of cubic feet of gas daily. For this purpose there is required something like a million or a million and a quarter tons of coal per year, and, in addition, about one hundred and thirty million gallons of oil for the same period of time. The gas is distributed through about three thousand miles of mains, which have gradually increased from six inches in diameter, which was the size used in 1826, to mains sixty inches in diameter, used at the present time. The gas distributed by these mains is watched with great care, to insure good service to the consumer. Last year the Consolidated Gas Company alone answered two thousand and four hundred calls for various kinds of assistance to the consumers.

No matter what may be said to the contrary, gas is the cleanest and most perfect of fuels in modern times. Of the various appliances, such as gas ranges, hot-water apparatuses, etc., an

*William Murdoch, in 1792, appears to have been the first to conceive the idea of manufacturing coal gas for lighting purposes, and in 1798 the factory of Boulton & Watt, at Soho, near Birmingham, England, was lighted by him with the new illuminant. It was Winsor, however, who introduced gas lighting to the notice of the English public. He had examined the installation of Lebon in Paris, and immediately went to London, where he met with considerable support, since in 1815 there were in use more than 4,000 of Argand's gas lamps, to supply which there were twenty-six miles of gas mains laid in the streets. Since that time, the advance of gas manufacture has been rapid indeed, and it has eventuated in a highly important industry.

The manufacture of coal gas in the United States is of especial interest. In 1802, the city of Richmond, Va , had been lighted by gas made from wood; and resin and coal (probably imported from Newcastle) were used by the Baltimore Gas Company in 1817, but probably about 1820 this company used American gas coal. Whale oil was used in the New York City Gas Works in about 1825, and was superseded shortly afterwards by resin. Pittsburgh coal was first used in the gas works of Philadelphia in 1836, and resin and foreign coals were used in the Manhattan Gas Works, New York City, in 1835 and 1837. American coal ("Clover Hill," Va., mineral) first appears on the records of the Manhattan Gas Company in 1850. Before 1830, the American coal gas industry was in its infancy. In 1823, the gas supplied by the New York Gas Light Company brought it $10.00

efficiency of sixty to eighty per cent. of the total heat of the gas can be used economically. It is believed that within the next twenty-five years none but the very wealthiest people will use solid fuel in our cities. Gas will be the most economical and rational fuel.

As a matter of fact, in most of the cities of the United States there are two kinds of gas manufactured, coal gas and so-called water gas. Both kinds of gas are made by the destructive dis-

FIG. 176.—RETORT BENCHES (FRONT), ASTORIA GAS PLANT, NEW YORK.

tillation of coal or oil or both; that is to say, in the first case the coal is heated in a closed vessel until it is decomposed and the gas is driven out, but in the second case hard coal is made incandescent, or "blown up," as it is called, by means of air blast, steam is then forced through this incandescent coal, and as it passes the steam produces what is called water-gas, which

per 1,000 cu. ft., but in 1859 gas was sold at from $2.50 to $3.00 per 1,000 cu. ft. About 1860 this company supplied about 13,000 consumers and 3100 street lamps.

Murdoch had compressed coal gas and had employed it as a substitute for lamps and candles; but John Taylor, of Stratford, Essex, England, in 1815, took out the first patent for producing gas by the decomposition of oils, which process resembles in principle that at present employed. In 1819, Gordon and Heard patented the compression of such gas. Faraday, writing in 1825, discussed the products obtained during the decomposition of oil by heat and referred to the operations of the Portable Gas Company. However, compressed oil gas was soon replaced by its rival, coal

has no illuminating value, but serves as a carrier for oil gas made at the same time and in the same apparatus; this oil gas is also produced by the destructive distillation of the oil.

It will not be practical to consider these processes together, so the older method of making illuminating gas will be presented first.

The method first used about one hundred years ago and still in use, was that of heating soft or bituminous coal in closed

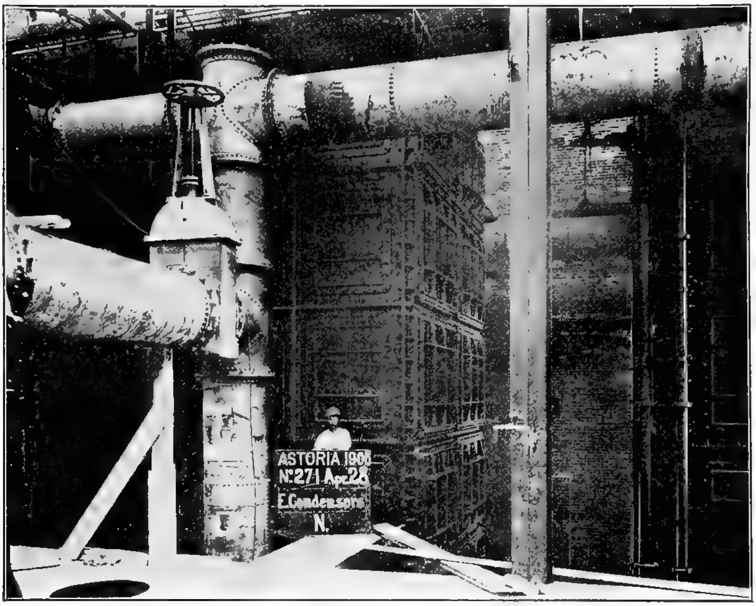

FIG. 177.—CONDENSERS, UPPER SECTION.

vessels called retorts, which are practically iron tubes or cylinders. These were placed over a fire which was capable of heating them to a temperature of 1,500° to 2,000° F.

gas, and it was not until 1871 that it was used satisfactorily in illuminating railway carriages in Germany. It was then reintroduced into England (1876), and since that time has found extensive use.

Water gas, which may be said to have originated with Fontana in 1780, was made the subject of patents by the Gengembres in 1817 and 1819, and by Vere and Crane in 1823, since which time many processes have been devised for its production. Michael Donovan was the first to actually make and distribute water gas. In 1830, he employed it for public lighting in Dublin, Ireland, but without much success. Water gas has been largely made in the past in parts of this country where coal gas was found to be expensive, and, when manufactured for domestic use, usually has been "carbureted" by means of naphtha or crude petroleum, a development of the process devised by Ibbetson, in 1824. The Kirkham process of 1852-4 was tried at the Municipal Gas Light Company's works in New York; the Sanders process of

The products obtained by heating soft or bituminous coal (which is also called gas coal) are, first, coke, which remains behind in the retort; second, a fluid, called tar, which passes out of the retort in the form of vapor, together with water formed in the coal, which produces what is called ammonia

FIG. 178.—CONDENSERS, LOWER SECTION.

liquor; and finally the gas, which contains other impurities, such as carbon dioxide and sulphureted hydrogen.

Sulphureted hydrogen, which has a very bad color, darkens many objects, as paints containing lead pigments, and in burning produces sulphur acids, more or less irritating and destruc-

1858 was installed in Philadelphia, Pa.; Wilmington, Del.; Aurora, Ind.; Laconia, N. H., and elsewhere; in 1864, the Gwynne-Harris process was experimented with in Elizabeth, N. J., and in 1873 it was introduced into the works of the Citizens Gas Company, Brooklyn, N. Y., but did not remain long in use; the Beatley process of 1875-6 was installed in the Peoples' Gas Company, Brooklyn, N. Y., but was shortly discontinued; and other processes and systems have been used in Rochester, N. Y.; Reading, Pa.; Dover, N. H.; San Francisco, Cal.; Atlantic City, N. J.; Chicago, Ill.; Saratoga, N. Y.; New Orleans, La.; Albany, N. Y.; Utica, N. Y.; Boston, Mass., and in many smaller cities and towns. All processes used in the past in this country have passed away, and the only one left in existence is that invented by T. S. C. Lowe and installed in nearly every gas works in California. Processes for producing blue water gas have been introduced at Troy and Yonkers, N. Y., and at Bridgeport, Conn., but without success. From 1888 to 1893, about twenty other plants using various processes were launched in the United States; none of these, however, was commercially successful.—(C. B.)

tive; so in order to fit the gas for the consumer, the gas is purified by passing through some material which will absorb the sulphureted hydrogen, also called hydrogen sulphide.

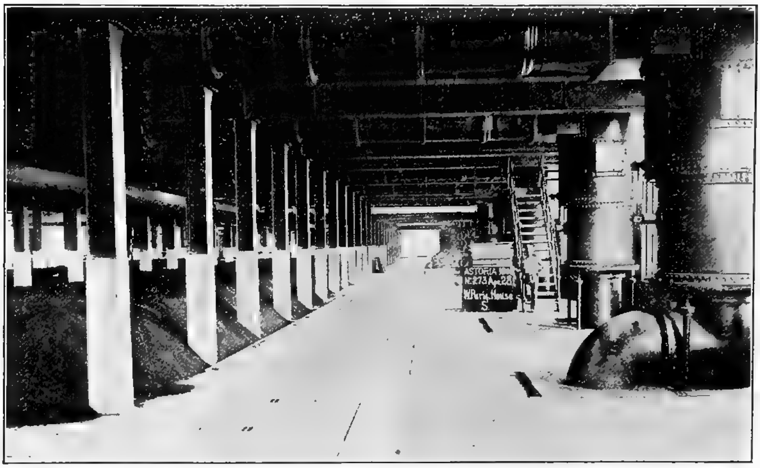

FIG. 179.—PURIFYING BOXES (UNDER SIDE), SHOWING MATERIAL USED.

Other pieces of apparatus must be used to further purify the gas. The tar forms the smoke of the crude gas coming from

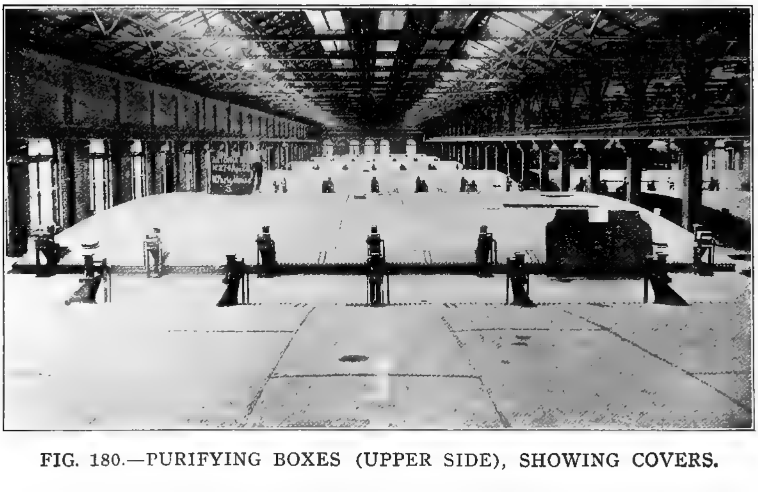

FIG. 180.—PURIFYING BOXES (UPPER SIDE), SHOWING COVERS.

the hot retort. In order to get rid of this smoke and make it form tar, it is passed through a cooling apparatus, where the

smoke comes into contact with cold surfaces, cooled by running water over them. The ammonia liquor, or water, as it is sometimes called, is removed by passing the gas at a further stage of the process through towers filled with wooden laths and slats, which are maintained in a wet condition by allowing water to run over them. As the ammonia liquor is produced, it is run away into a tank for use afterwards as a by-product. The gas

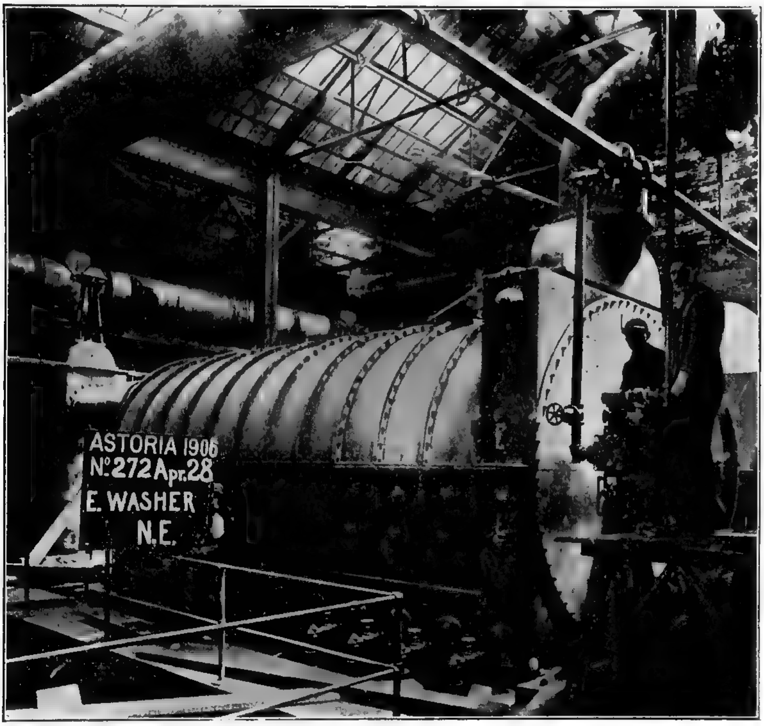

FIG. 181.—AMMONIA WASHER FOR COAL GAS.

leaving the ammonia washers, as they are called, passes into square boxes containing layers of a mixture of shavings and iron oxide. The shavings are to make the mass porous, and the iron oxide is for the purpose of removing the sulphureted hydrogen. From this point the gas passes into a gas-holder after being measured in a meter, and finally reaches the consumer in his house through gas mains in the streets of the city.

Briefly then, the *coal gas* process consists in heating coal in the retort and producing coke, which remains behind; producing tar, which remains in the condensers (coolers), and the ammonia water in the washers, together with sulphureted hydrogen, which stays in the purifying box, and the gas which passes through the station meters to the mains and thus to the consumers. The coke, the tar and the ammonia-water are all called by-products and are used for various purposes. In Europe the

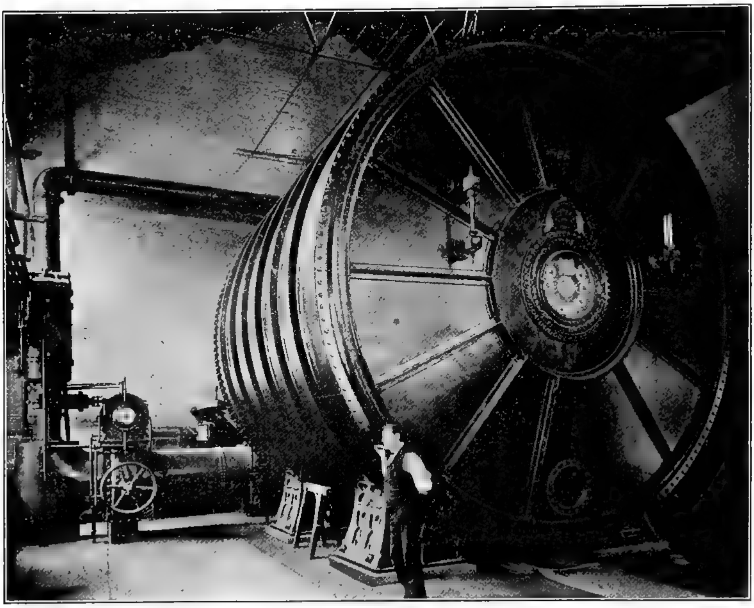

FIG. 182.—A STATION METER FOR MEASURING GAS.

purifying material which takes out the sulphureted hydrogen is also used, but in the United States this by-product is not yet utilized. A ton of coal will produce about two-thirds of a ton of coke, thirteen gallons of tar, about twenty pounds of ammonium sulphate from the ammonia water, and between eleven and twelve thousand cubic feet of gas. These are approximated figures, and depend largely on the character of the coal and the management of the heating of the retorts.

The usual features of the *water gas* process consist first in heating up a large mass of hard coal or coke in cylindrical

furnaces, holding from ten to twenty tons of coal each, according to the demands of the town or city where the gas is manufactured. Each of these cylindrical furnaces is furnished with a set of grate bars, tubes and pipes for the admission of air and steam respectively. In these large cylinders a fire is started with wood, the coal is piled on top of the thoroughly ignited wood,

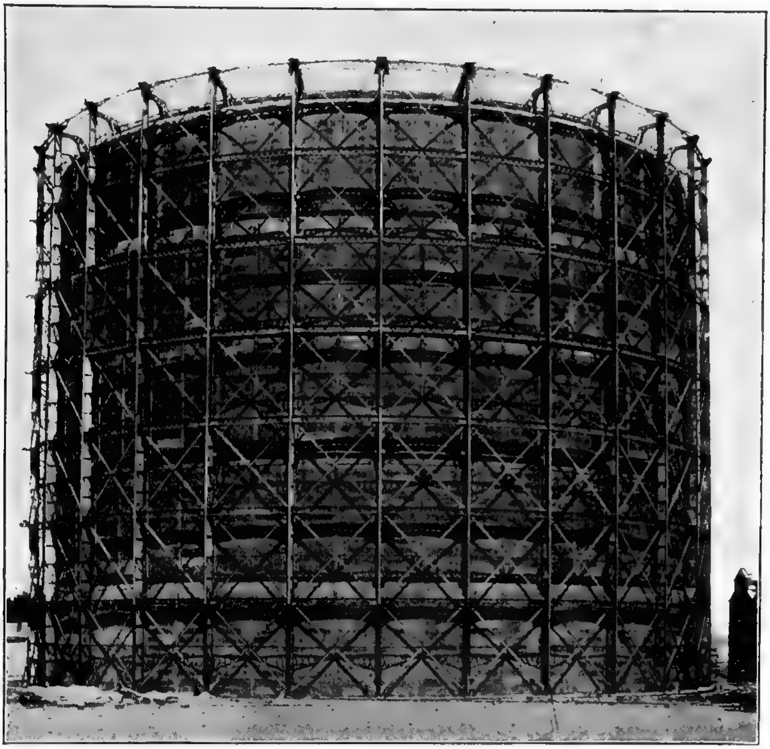

FIG. 183.—LARGE GAS HOLDER.
It has a wooden structure, level with the ground, to support the top. A boat is kept within to be used in making repairs.

and the air blast turned on. Then gradually coal or coke, as the case may be, is placed in the cylinders until they are full of hot coal or coke. At this point, the air is shut off tightly and the steam admitted at a point below the grate bars, which as it passes through a mass of white hot fuel is decomposed, the oxygen of the steam uniting with the carbon of the coal forming

carbon monoxide, and the hydrogen of the steam is set free. This gas mixture burns with a blue flame and is the basis of the manufacture.

While we are heating up the fuel to make it white hot, and while the air blast is still operating, the products of combustion involved during this operation are allowed to traverse two cylinders of practically the same size as the coal furnace; but these are not filled with coal or coke and contain only fire brick so arranged as to form checker work through which the products of combustion in an intensely heated condition are forced to travel.

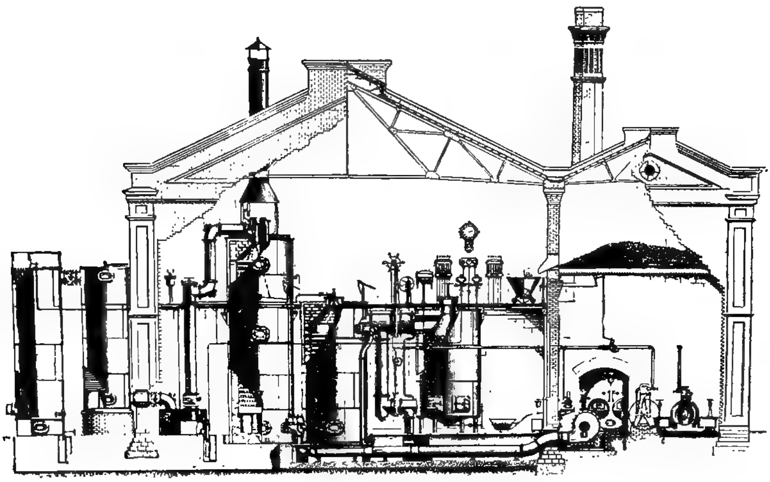

FIG. 184.—CARBURETED WATER GAS GENERATORS.
(Humphreys and Glasgow.)

The result of the passage of these heated products through the fire brick of these cylinders is to make them intensely hot, so that when the fire is sufficiently hot from the blast, and before the steam is turned on underneath the grate of the furnace, into the first of these hot cylinders a small stream of oil is distributed over the bricks by a spraying process. The heat of the bricks evaporates the oil and turns it into a vapor. It will be seen then that when we put steam under the grate bars and oil into the second cylinder containing the fire bricks, at the entrance to the third cylinder, we shall have water gas (carbon monoxide and hydrogen from hot coal) together with the oil

vapors from the heated second cylinder. The third cylinder is for converting the vapors of the oil produced in the second cylinder into permanent gas, so that a mixture of decomposed oil vapors with hydrogen and carbon monoxide leaving the third cylinder is what is known as "carbureted water gas." From this point the process of purification is practically the same as that for coal gas—that is to say, we have condensers which take out the smoke of the gas and turn it into tar by cooling the gas. We also have a washer to take out still more tar, also a cylinder filled with shavings to remove the last traces of tar, and finally purifying boxes with the mixture of the shavings and oxide of iron for the sulphureted hydrogen, which is also incident to the water gas process as well as to the process of making coal gas. The real difference in the purification of the two kinds of gas is that there is no ammonia in the water gas nor any cyanogen, and with these exceptions the process is practically the same, except perhaps the trouble with the tar matters of the water gas process as they are more difficult to remove than those of the coal gas.

The two gases are mixed, after being purified, by passing them together into the gas holders in most cities in the United States, the usual practice being to have the coal gas works operated steadily all the year round and to work the water gas process so that the increase or decrease of consumption can be provided for. It is easier to start up a water gas plant than it is to start up a coal gas plant. The final gases produced are called illuminating gas and both as regards the heat units as well as the candle power are alike, and for all practical purposes are the same. Neither gas can be respired nor taken into the lungs, and either gas should be carefully taken care of and not allowed to escape.

The illuminating gas so produced (both coal and water gas) consists of a mixture of the following gases:—

	Coal Gas.		Water Gas.
Carbon dioxide....................	1.5	to	3.0%
Illuminating hydrocarbons..........	3.0	"	10.0 "
Oxygen	0.5	"	1.0 "
Carbon monoxide..................	6.0	"	26.0 "
Hydrogen	45.0	"	30.0 "
Marsh gas........................	40.0	"	24.0 "
Nitrogen	4.0	"	6.0 "

These constituents have different values when the gas is used. The carbon dioxide and nitrogen are inert and of no value. The oxygen assists combustion. The carbon monoxide, hydrogen and marsh gas produce heat and practically no light, while the illuminating hydrocarbons give both heat and light. The proportions of the different constituents in any illuminating gas will vary according to the mixture of water gas with coal gas as sent out to the consumer from the gas-holders.

CHAPTER XX

The Valuation of Illuminating Gas.

ARTHUR H. ELLIOTT, Ph.D.,
Engineer-Chemist to the Consolidated Gas Co., New York City.

The gas which we burn in our houses and which is commonly called Illuminating Gas, is not only valuable for its illuminating power, but also for its heat value and from the latter its mechanical force or energy.

At the very beginning of its manufacture, a hundred years ago, it was seen that some standard must be adopted to determine its value as an illuminating agent, so that it might be compared with other sources of illumination. At that time two sources of artificial illumination were in use, oil and candles, which were almost universally in vogue in domestic life. By far the most popular was the candle, made either from wax or a solid fat, like tallow. A tallow candle being quite common and used by the larger portion of any community was therefore looked upon as a unit of comparison. Naturally the new illuminating gas was compared with the tallow candle, and the first promoters of the new industry boasted about the number of candles it would take to be equal to the flame of the new gas. Another point which must not be forgotten is that the new illuminant could be used without any trouble; the flame did not require snuffing. Where a large number of candles were used it is obvious that somebody must attend to the snuffing of them. This was used as another argument in favor of the use of gas, and the candle became the unit of comparison.

The mode of comparing a gas flame with a candle was simple enough at the beginning.. It consisted in the use of a stick casting a shadow on a white surface. The two lights, a candle and the gas flame, were placed in such a position that they cast two shadows on a white surface. At the same distance from the white surface the gas flame cast a darker shadow than the candle; but by moving the gas flame farther and farther from the white

surface a position is reached at which the densities of the two shadows are equal, and it is obvious that they are giving the same amount of light upon the white surface, since they cast equally dense shadows upon it. The relative distance between the candle and the white surface and the gas flame and that surface is the comparative value of the gas flame to the candle. The farther the gas flame is away from the white surface, the candle remaining stationary, the higher its value as an illuminant compared with the candle. But the mere measurement of the distance between the white surface and the candle and the white surface and the gas flame, and dividing one by the other, will not give the true relationship between the two sources of illumination.

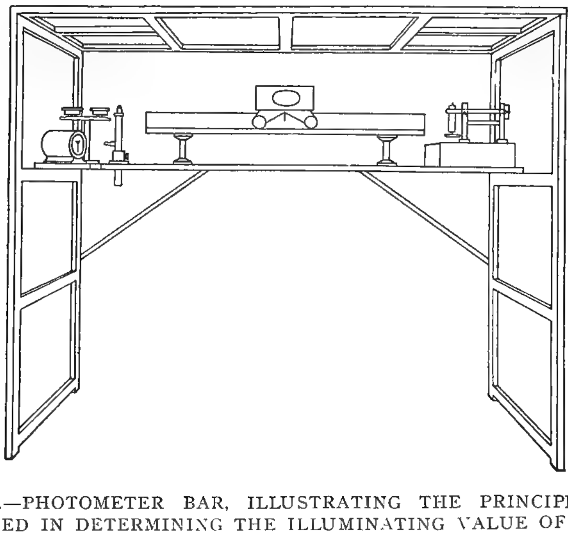

FIG. 185.—PHOTOMETER BAR, ILLUSTRATING THE PRINCIPLES INVOLVED IN DETERMINING THE ILLUMINATING VALUE OF GAS.

Recourse is therefore made to one of the laws of light, which is that the amount of light falling on any given surface is inversely as the square of the distance of the surface from the source of light. Therefore, in the method of comparison mentioned above, by squaring the distances between the white surface and the two flames and dividing the candle figures into the gas flame figures, a true comparison can be made. Suppose, for example, that the distance between the candle and the white surface is 12 inches,

and the distance between the gas flame and that surface is 48 inches; the figures become

$$\begin{array}{l} \text{Square of } 48 = 2304 \\ \text{“} \quad \text{“} \quad 12 = 144 \end{array} \quad \frac{2304}{144} = 16,$$

and we say that the gas is 16 candle-power.

But it soon became evident that a mere comparison of a gas flame with a candle flame was not exact enough for a fair comparison of the value of the two illuminants. Candles did not burn alike, and some gave more light than others for various reasons connected with their manufacture,

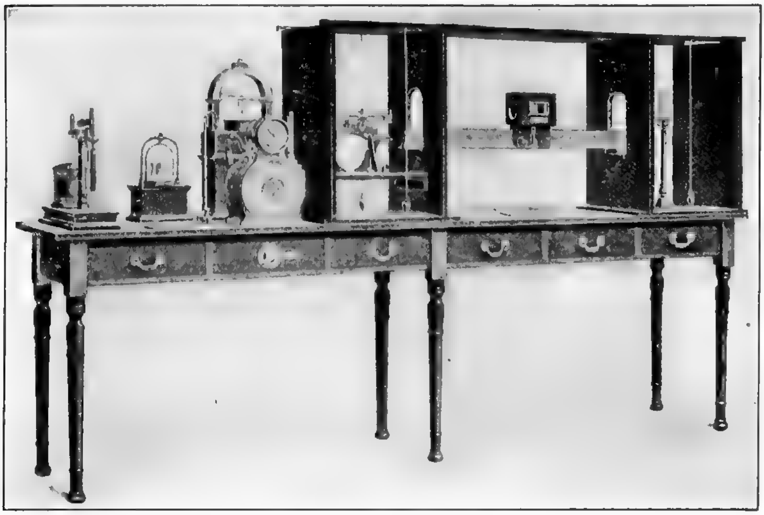

FIG. 186.—"LETHEBY" PHOTOMETER.

which was somewhat crude in old times. Again, it is obvious that gas flames may vary according to the kind of burner used and the quantity or volume of gas passing through that burner. Therefore, after a good many discussions, it was decided to adopt a special make of candle and also to burn the gas in a definite kind of burner at a determined rate. It took many years to carry out these ideas, and acts of Parliament were passed in England and in various parts of Europe to make laws that should regulate the manner of selling gas to the people who desired to use it. It is now generally agreed to among those in

authority that the standard candle is one made of spermaceti, and so made that it shall burn 120 grains of its material in one hour; the light given by such a source of light is called a "candle-power." In order to compare gas with it, the gas must be burned in a burner having a special construction, but it is not decided universally which burner this shall be; and it is very important, because some of the best gas burners made give marked differences in value of illumination when burning exactly the same volume of gas per hour. In the city of New York, the standard burner is what is called a Bray Slit Union No. 7, and is practically the best burner of its kind, because it is readily candle and the gas flame which we have been discussing. It is foolish to burn gas in burners that are cheap and badly made. It requires skill and attention to make good gas burners.

In the laboratory of every good gas company will be found an instrument called a Bar Photometer, or light measure. This is built and arranged to carry out the comparisons between the candle and the gas flame, which we have been discussing. It consists of a bar, usually 60 inches long, at one end of which is placed a pair of standard candles and at the other end a standard burner (in New York City a No. 7 Bray Slit Union). On the bar and between the lights is a sliding box with mirrors and a disk, placed at right angles to the length of the bar, so arranged that both sides of the disk can be seen at once when viewed at right angles to the length of the bar. As the disk is made of thin paper and a portion of it is almost transparent, part of the light falling on it from either side will be reflected and part will be transmitted through the thinner section. By removing the disk between the two sources of light, until the opaque surfaces and the translucent surfaces are equally illuminated, a point is reached where the line of demarkation between the opaque and translucent surfaces disappears, and both sides of the disk are equally illuminated. This system of disk and mirrors is due to Dr. Robert Bunsen of Heidelberg, the father of photometry and gas analysis.

At the candle end of the bar is a balance (scales) for weighing the candles, so that correction can be made when the candles burn more or less than 120 grains per hour, which is the standard rate. If the candles burn more than 120 grains, the gas flame is

correspondingly weaker, or *vice versa.* Two candles are used instead of one, the light irregularities in one being assumed as corrected by the other, but they very rarely burn 120 each per hour; hence they have to be weighed before and after being used for the test.

At the gas end of the bar and attached to the burner is a meter to measure the gas used in the test; and attached to the meter is a governor (or regulator), which regulates the rate at which the gas shall burn. In New York City and when using a No. 7 Bray Slit Union burner, the rate is five cubic feet per hour, or one-twelfth of a cubic foot per minute. A clock striking minutes is found in the photometer room, or in most cases is in the same case with the meter. A pressure-gauge containing water is also furnished, as the gas is usually burned at a pressure of less than an inch of water while making the test of candle-power. It will be seen that by weighing the candles and measuring the gas, a very close measurement of their relative value will be obtained.

In addition to the candle-power of the gas used in our houses, it is quite important to know its heating value. Anyone who notes the course of events and keeps in touch with the progress of manufactures, will see that the day is not far distant when coal will be abandoned as a source of heat in our homes, and gas will be used exclusively, being very much more convenient.

The heating power of gas is determined by ascertaining how many pounds of water can be heated with the combustion of one cubic foot of gas. The standard in this case is the heating of one pound of water from 32° to 33° Fahrenheit. This is called the British Thermal Unit (abbreviated B.T.U.).*

There are a number of pieces of apparatus made to ascertain the heating value of the gas; one of the best was devised by Karl Junker, of Dessau, Germany, and is very largely used. It consists of a double set of vertical tubes in a jacketed case, the tubes being surrounded with water. The gas is burned under one set of these tubes and the products of combustion pass down the other set and escape to the atmosphere. A stream of water

*In general scientific thermal measurements, the *calorie* is the standard heat unit, and represents the heat required to raise the temperature of one kilogram of water from 15 degrees C. to 16 degrees C. A B.T.U. is the heat required to raise the temperature of one pound of water 1 degree F. at its temperature of maximum density; therefore, it is 1/3.968th part of a calorie.

is kept circulating around the outside of the tubes, while the products of combustion pass through the interior. By carefully

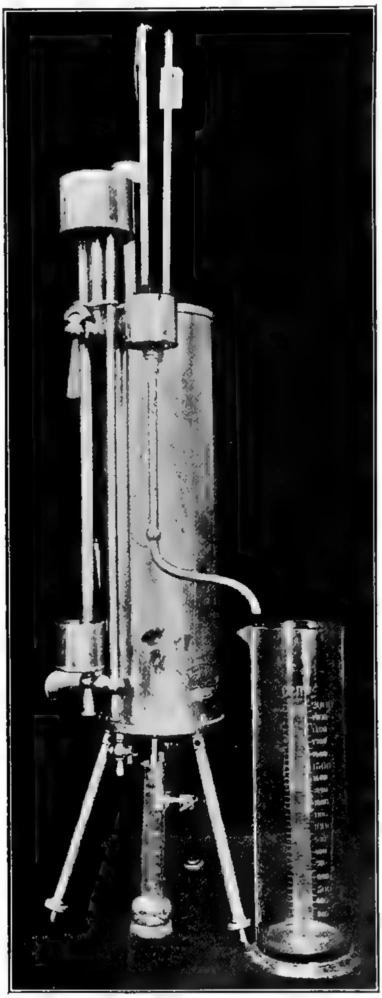

FIG. 187.—JUNKER'S CALORIMETER (EXTERIOR) WITH WHICH THE HEATING VALUE OF GAS IS DETERMINED.

adjusting the flow of the water around the tubes, every unit of heat in the gas can be tranferred to the circulating water, and the products of combustion pass into the atmosphere at the same

temperature as the air entering the apparatus around the burner. By measuring the amount of gas burned and the weight of the

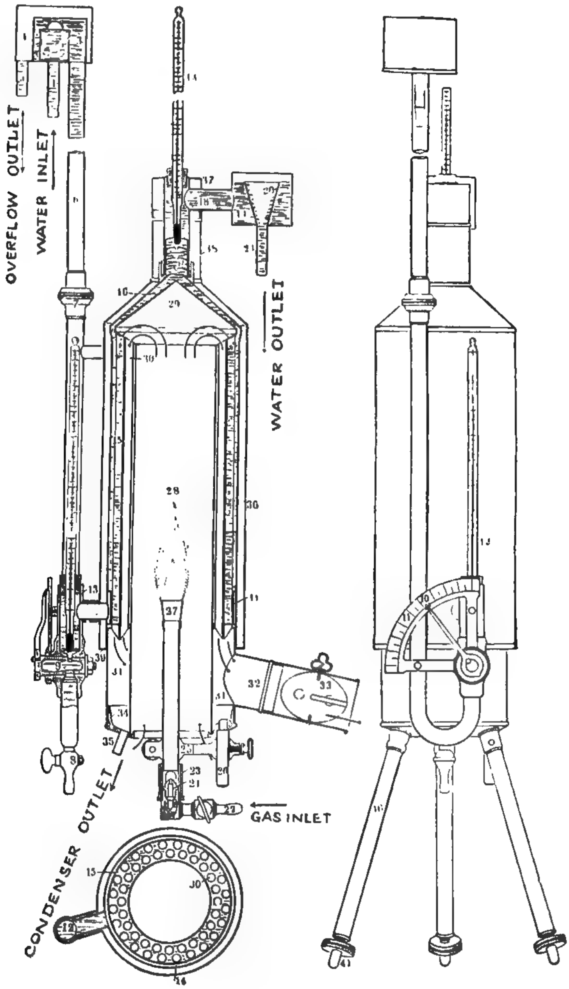

FIG. 188.—SECTION SHOWING INTERIOR OF A JUNKER'S CALORIMETER WITH WHICH THE HEATING VALUE OF GAS IS DETERMINED.

water heated, we ascertain the heating value of the gas. The heating value of the gas supplied to most American cities varies between 500 to 600 B.T.U.

Another method for determining the heating value of gas is by calculation from the chemical analysis of the gas mixture. From what was said about the constituents of illuminating gas and from the figures given in connection with the constitution of coal and water gases, in the preceding chapter, it is evident that we can analyze these gases, or a mixture of them. Furthermore, by taking the pure constituents, such as hydrogen, marsh gas, carbon monoxide and illuminants, and by finding the heating value of each, it is seen that by applying the figures thus obtained, and knowing the percentage of each constituent in the gas mixture, we can give the true heating value of it quite accurately. Indeed the figures so obtained vary very slightly from those obtained with the Junker calorimeter. Therefore, if a gas analysis is available, the heating value in British Thermal Units can readily be calculated.

This brings us to the next and one of the most important steps in our discussion of the value of gas, viz., gas analysis. Several hundred years ago chemists found out that various gases were soluble in certain liquids; indeed, all gases are soluble in all liquids more or less. For example, a solution of some alkali, such as soda, potash or lime water, will dissolve carbon dioxide. Sulphuric acid will dissolve what we call illuminants in the gas. A mixture of pyrogallol, an organic substance, with a solution of soda or potash, will dissolve oxygen, and so on through the whole list of kniwn gases.* Every gas can be absorbed, we say, by some liquid best suited to the purpose, some of these liquids being solutions of solids or mixtures of solids.

With these facts well established, Robert Bunsen devised a system of gas analysis which is the basis of all the systems in use today. It is not necessary to go into the history of the various steps leading to the adoption of the modern methods, but a simple description of the methods now used will be sufficient to bring about an understanding of the *modus operandi* of them all.

The gas mixture to be analyzed is placed in an apparatus consisting of a series of glass tubes so arranged that the gas

*The nitrogen and argon of the air are not absorbed sufficiently by any known liquids to make their determination by such methods of value. They play the part of diluents in fuel or illuminating gas and are determined together and by difference.

can be transferred from one tube to another readily, and certain liquids can be brought into contact with the gas mixture in the tube without losing any of the mixture. Let us suppose that we have 100 volumes of gas mixture in a vertical glass tube, connected by rubber tubing with another glass tube placed alongside of it, and containing water which fills the second tube and reaches to the base of the gas column in the first tube. If we now, by means of a glass stop-cock attached to the top of the first tube, run into this tube a solution of soda, any carbon dioxide in the mixture will be absorbed, and the column of water will rise and replace the volume of gas dissolved. If we had the tube divided into 100 parts, and it was full of gas, and if we now

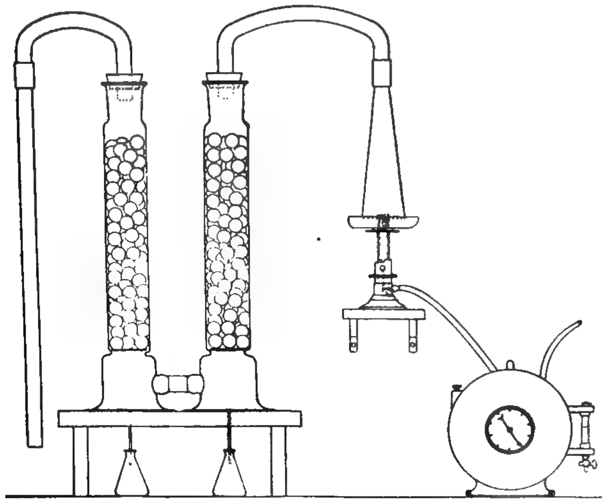

FIG. 189.—ELLIOTT APPARATUS FOR DETERMINING SULPHUR IN GAS

have only 97 parts in the tube, it is evident that the gas mixture contained three parts of carbon dioxide.

This method of procedure is followed for all the constituents of the gas mixture and we ultimately know the volume of each gas in such a mixture.

From what has been said about all liquids dissolving all gases, it may be asked, does not the soda solution added to take out the carbon dioxide also take out some of the other gases in the mixture? It does; but only in small quantities, and as the amount

of liquid added is only about enough (a matter of practice) to take out the carbon dioxide, the other constituents are not much affected. Of course a certain order of application of the liquids is necessary, otherwise the system could not be used. The usual order is to use, first, soda to remove carbon dioxide; second, sulphuric acid or bromine (another absorbent of illuminants) for the illuminants; third, a mixture of pyrogallol and soda solution for oxygen; fourth, a mixture of cuprous chloride in hydrochloric acid for carbon monoxide. At this point the use of ab-

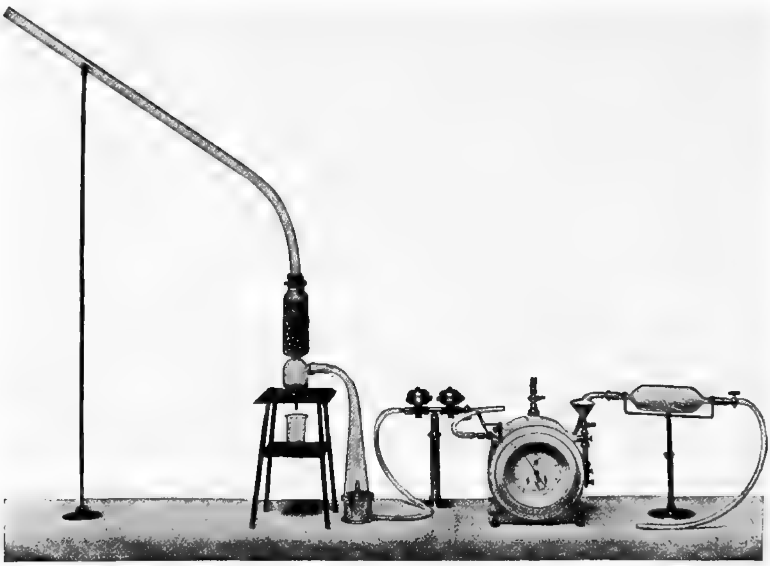

FIG. 190.—REFEREE'S APPARATUS FOR DETERMINING AMMONIA AND SULPHUR IN GAS.

sorbing liquids is discontinued. The remainder in the mixture consists of hydrogen, marsh gas, perhaps a little ethane, and nitrogen gases. To determine the quantity of each of these an explosion or combustion of the residue of the mixture has to be made. For this purpose a portion of the residue is transferred to another glass tube carefully graduated and with platinum wires in its sides, and mixed with a known volume of air. The mixture is then ignited by means of an electric spark through the platinum wires and the combustion or explosion is completed.

Since the gases in the mixture are only hydrogen and hydrocarbon gases, the result of the explosion is carbon dioxide and water vapor, the nitrogen remaining unchanged. From measurements of the contraction (from water vapor) and the carbon dioxide absorbed by the sodium hydroxide solution, a calculation is made which gives the volume of the marsh gas and hydrogen in the portion of the residue used for the explosion, and from this the percentage of these gases in the original mixture can be ascertained also by calculation. Of course the kind of apparatus used for the analysis and the skill of the operator have much influence on the results obtained. But with reasonable care and attention to details, accurate results are obtained with most of the modern apparatus designed to carry out gas analysis upon the system here described.

At a very early date in the manufacture of gas, it was ascertained that two constituents of the crude gas were very injurious when the gas is burned, viz., sulphur and ammonia. These two materials, the first as sulphureted hydrogen and carbon disulphide, the latter as ammonia gas, by oxidation through combustion, become sulphuric acid and nitric acid respectively. In order to limit the amount of these gases present in our domestic illuminating gas, laws have been passed stipulating the quantity of each that the gas shall contain. In New York City the limit for sulphur is 20 grains in the 100 cubic feet, and the limit for ammonia is 4 grains per 100 cubic feet. As a matter of fact, these limits are rarely, if ever, approached. The sulphur is readily removed in the process of purification, and the ammonia is saved as a valuable by-product to be used for agriculture.

Such is a most brief outline of the methods of ascertaining the domestic value of coal and water gases. Many valuable treatises have been written on the subject which are familiar to the experts. Sufficient has been given, however, to acquaint the layman with the important points to be considered in a city's gas supply, and to impress the need of having the advice of able and honest chemical engineers.

CHAPTER XXI

The Smoke Problem; With Some Special Applications to New York City.

PAYN B. PARSONS, M.D.,
Formerly of the Metropolitan Sewerage Commission; Bacteriologist with the Lederle Laboratories, New York City.

The word "smoke" is a rather broad term. Strictly speaking, smoke is composed of the volatilized products of the combustion of an organic substance, such as coal, wood, etc., charged with fine particles of carbon. These small particles of carbon are

FIG. 191.
Leeds, England; overlooking Kirkstall Road. (From photograph.) This scene may be observed any hour of the day in Leeds.

finally deposited as soot of a sticky, tarry nature, which settles and adheres to everything with which it comes into contact.

The black smoke which escapes from a chimney or a smoke-stack when soft coal is thrown upon a fire is due to imperfect combustion of the fuel. If this same black smoke should be made to pass over a mass of coal in active combustion with

ample air, the particles of carbon would be consumed. The carbon would combine with the oxygen of the air and be changed into colorless, harmless carbon dioxide. The conditions necessary for perfect combustion are seldom all present. The temperature must be raised as rapidly as possible so that the atmospheric oxygen may combine with the carbon and the hydrogen, and this temperature must be steadily maintained so long as the coal is being fed to the boilers. The oxygen must be brought into close

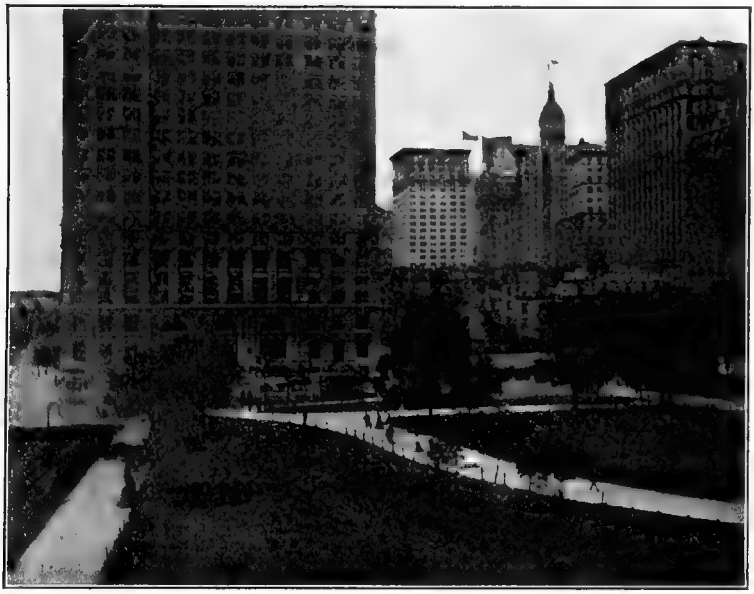

FIG. 192.—A VIEW OF DOWN-TOWN SKYSCRAPERS FROM BATTERY PARK, SHOWING VERY LITTLE SMOKE ISSUING FROM THESE TALL BUILDINGS, EACH OF WHICH OPERATES ITS OWN POWER PLANT.

contact with the coal newly fed to the fire and with the imperfectly consumed products of a previous feeding.

This means that it seldom happens that all the carbon and oxidizable compounds of carbon are converted into carbon dioxide. The prevention of the black smoke means a complete combustion of the fuel. When a large quantity of coal is thrown on a fire, the air passages are closed up and a scarcity of atmospheric oxygen results. If the coal could be fed gradually and uniformly, as is done by automatic feeding devices, and the air

supply maintained, the combustion would be complete and there would be no smoke nuisance.

If the additional air needed cannot be supplied from below, it may be introduced above the grate through the door or through flues at the sides of the furnace, being drawn in by the action of steam jets or forced in by a blower. The air or steam may be turned on or shut off as desired. The draft in a boiler may also be increased by making the chimney higher and in this way more complete combustion results.

FIG. 193.—A VIEW OF NEW YORK ROOF-TOPS. NO SMOKE IS VISIBLE.

In the city of New York, the use of hard or anthracite coal is almost universal, and so long as this practice is continued the danger from the smoke nuisance is slight. In a large modern city like New York, too, the fact that gas and electricity are extensively used for heating and for power contributes to the prevention of smoke nuisance.

Many of the boats passing along the water front, especially the tugs of certain lines, cause a decided smoke nuisance. In offices located near the rivers or the Upper Bay, the desks and

papers often receive a considerable deposit of soot. This matter is a rather difficult one to remedy, unless the nuisance occurs while the boat is tied up to a dock, on account of the Hudson River being a State line.

The problem of smoke abatement has been a vital one for many centuries. Some six hundred years ago, the citizens of London petitioned King Edward I. to prohibit the use of "sea coal." He replied by making its use punishable by death. This stringent measure was repealed, but there was again considerable complaint in Queen Elizabeth's reign and the nuisance created

FIG. 194.—ANOTHER VIEW OF NEW YORK ROOFS.
In the distance can be seen the chimneys of one of the largest power plants. This condition would not be possible with the use of soft coal.

by coal smoke seems to have been definitely recognized at this period. Since that time there has been continual agitation, together with much legislation, both abroad and in this country. In the seventeenth century, King Charles II. adopted repressive measures in London, and in the present century anti-smoke crusades have been frequent. In fact, the smoke problem will undoubtedly continue to demand attention until it is either entirely solved by the abolishment of the use of solid fuel, or by the in-

stallation of devices and methods which will prevent the formation of smoke in furnaces, regardless of the nature of the fuel.

The economy resulting from smoke abatement is a potent argument in its favor. This phase of the problem has little to do with the ethical side of the subject, however, since all communities have the right to demand its abatement regardless of economic considerations. In this connection, it is appropriate to call attention to the legal status and different phases of the smoke problem.*

"Every individual has the right to have the air distributed over his properties and habitation in its natural condition, that is, free from all artificial impurities. In fact, it may be stated that no one has the right to interfere with the distribution and amount of pure air which flows over another's land any more than he has to interfere with his neighbor's soil. This right is strictly a natural one, and every use of property that causes an unwarrantable impregnation of the air with foreign substances to the detriment of another, is a nuisance. The air must be as free and pure as can be reasonably expected.

"It is laid down broadly as a general rule in law that any act, omission or use of property which results in polluting the atmosphere with noxious or offensive gases or vapors, thereby causing material physical discomfort and annoyance to persons residing in the vicinity, or injury to their health or property, is a nuisance.

"The question as to what degree of impurity imparted to the atmosphere by one in the use of his property constitutes a nuisance, is one of fact, and is determined by the jury from the circumstances of each case. Injury is, of course, a question of compound facts. No precise tests may be given that are applicable to all cases. In the consideration of the surrounding circumstances of a case, the character and nature of the gas complained of is of prime importance, and the times and periods of the generation of the gas, or the constancy and frequency of the annoyance, the extent of the injury or inconvenience caused, and the nature of the business, its location, management, and manner of construction, must all be taken into careful consideration.

"Although diminution in value is the proper element of dam-

*Baskerville: *Eng. and Min. Jour.*, May 1st, 1909, pp. 884-87.

ages and in some cases the actual measure of the nuisance, yet it has been ruled in New Jersey that mere diminution of the actual or rental value of a property is not sufficient to make a business a nuisance. According to common law, a sensible injury is only a visible injury. If smoke and its accompanying gases cause sickness or injury to health, an action for damages lies, even though the fuel producing the nuisance is necessarily used. The Supreme Court of Maryland held that in determining the question of nuisance from smoke or noxious vapors, reference must always be had to the locality. For instance, a party dwelling in a city in the midst of crowded commercial and manufacturing activities cannot claim the same quiet and freedom from annoyance that he might rightfully claim in the country. When the population moves up to a nuisance which was previously in solitude, then, as a general rule, the nuisance must recede. It must, however, be reasonably offensive."

On its first introduction, gas was declared to be deleterious to the health of the community, and in some localities steam railways were at one time so offensive to particular local authorities, that attempts to prosecute them as nuisances were not infrequent. Grievances of prosecutors in such cases as pertain to damaging gases in particular are often sentimental or speculative—just as they were at the time when the use of gas as a fuel was regarded as a nuisance, without due regard to the substantiality of the thority to declare a public nuisance and forbid the same, but the "nuisance." The Health Departments usually possess full authority final determination of the nuisance rests with the courts.*

*The smoke nuisance is not a necessary one in New York, and there is enough legal machinery to prevent it, even if interests of economy do not work in this direction, by demanding the complete combustion of the fuel used. With regard to the emission of smoke as a nuisance, the Sanitary Code of the Department of Health of the City of New York states as follows:

Section 96—"The owners, lessees, tenants, occupants and managers of every blacksmith or other shop, forge, coal-yard, foundry, manufactory and premises where any business is done or in or upon which an engine or boilers or locomotives are used, shall cause all ashes, cinders, rubbish, dirt and refuse to be removed to some proper place, so that the same shall not accumulate at any of the above-mentioned premises or in the appurtenances thereof, nor the same become filthy or offensive. Nor shall any owner, lessee, tenant, occupant, manager, engineer, fireman or any other person cause, suffer or allow any cinders, dust, gas, steam or offensive odor to escape to the detriment or annoyance of any person not being therein or thereupon engaged.

"Nor shall any owner, lessee, tenant, occupant, superintendent, manager, engineer, fireman or any other person cause, suffer or allow smoke to escape or be discharged from any such building, place or premises or from any engine or locomotive used therein or thereon."

Section 1229 of Chapter XIX of the Charter of New York City defines the word nuisance as follows: "The word 'nuisance' as used in this act shall be held to embrace public nuisance, as known at common law or in equity jurisprudence; and it is further enacted that whatever is dangerous to human life or detrimental to health —and whatever renders the air or human food or drink unwholesome, are . . . nuisances."

As to the injury to health of people living in a smoke-laden atmosphere, it is certain that air charged with soot, dust and other particles is unwholesome. The tonic effect of sunshine and the depressing effect of a dark, gloomy day are well recognized facts and where the sun is obscured by volumes of black smoke, there can be no cheering effect from its rays.

A B

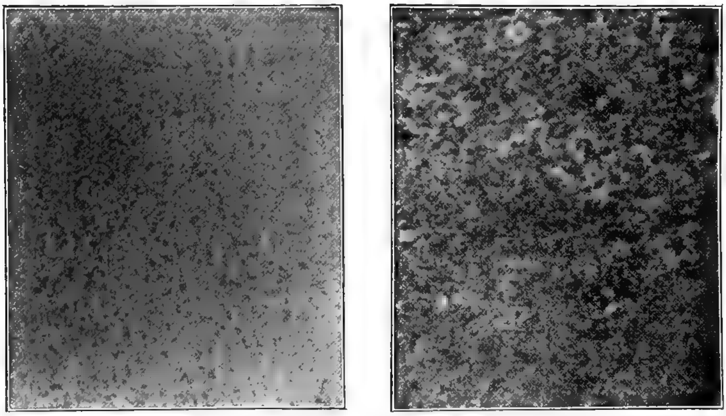

FIG. 195.—COAL DUST IN THE AIR OF TOWNS.

Dr. J. B. Cohen, of Leeds, England, exposed several glass plates, one foot square, in and around Leeds, but removed from the neighborhood of chimneys. The above cuts show the appearance which two plates presented after a year's exposure, one in the country and the other in town. "A" remained clean and transparent, whereas "B," exposed at a station in town, was quite opaque from sticky material in the town soot.

Sunlight is fatal to most pathogenic bacteria. To be cured of consumption, one leaves the city with its air more or less laden with smoke and dust, and lives in the pure clear air free from any polluting material of this sort.* Many of the respiratory diseases may be caused, or their development aided, by breathing

*The smoke problem as applied to the soft coal nuisance in New York City is a question mainly of prophylaxis. As compared with the cities of the Middle West, in what is often called the soft coal belt, the air of New York City is quite clear and free from smoke deposits.

The rigid enforcement of the sanitary code as applied to the smoke nuisance by the local department of health is the means of keeping this matter well in hand. Inspectors of this department are constantly on the lookout for violations of the code, and in case a complaint is made, the premises in question are watched for three consecutive days and a report made, often accompanied by photographs of the conditions found. A general inspection of the city will convince one that the smoke problem in New York at the present time is not a serious one by comparison with Leeds, Manchester, Cleveland or Pittsburg. It should be noted in this connection that the distressing smoke problem of the last mentioned industrial center is now being given attention by the authorities.

air filled with smoke and dust, and are not easily relieved, unless the sufferer changes his residence.

The fact that a deposit of soot on the face or hands or on the clothing of a cleanly person is annoying, is not to be disputed. Smoke is without question injurious to property. Residents of cities are only too well aware of the damage to draperies and other articles within their houses produced by dust in general and discoloration in particular that is attributed to soot. The destructive action, aside from that caused by the severe treatment necessary in frequent cleaning, is mainly due to sulphur dioxide, a constant impurity present in city air in quantities varying with the percentage of iron sulphide in the coal and the amount of coal burned.

Baskerville* made a number of determinations of the sulphur dioxide content of the air of New York City. Stations were established throughout greater New York, including the high office buildings, parks, subways, and railroad tunnels; and very variable results, as might be expected, were obtained. But he found that sulphur dioxide to the extent of 1,300 tons, calculated as 80 per cent. sulphuric acid, is discharged every twenty-four hours into the air of New York City from the combustion of coal alone.†

From an economic standpoint, this is an enormous, partly avoidable, waste; while from a sanitary standpoint, any disinfecting action it exerts on the organic wastes arising from the streets is greatly counterbalanced by its general injurious effects.

These may be thus summarized in the words of Baskerville:

"1. Its presence in atmospheric air is a menace to hygienic welfare, since it has serious effects on susceptible persons and particularly exerts deleterious effects upon the respiratory organs. SO_2 in the air of manufactories tends to produce bronchitis and anemia.

"2. It exerts an injurious action on plant life. In this action it is less violent than hydrogen chloride, sulphuric acid, and fluorine; but owing to its less solubility and consequent slower condensation, it has a wider distribution. In Manchester, England, in 1891, it was learned that

*Paper read before the Society of Chemical Industry, Feb., 1909; *Journal of Industrial and Engineering Chemistry*, vol. 2, No. 8.

†The determinations may, in part, be thus summarized:

Locality.	SO_2 in parts per million.
Elevated portion of the city, near a high stack	3.14
Various parks	0.84 (maximum; others negative).
Railroad tunnels	8.54—31.5
Subway	None.
Downtown region	1.05—5.6
Localities near a railroad	1.12—8.4

the greatest injury to plant life is due to the emanations from dwelling houses.

"3. The condensation of sulphurous acid with moisture in fogs and hoar frosts seriously affects goods printed with colors sensitive to sulphurous acid; for example, logwood, Brazil wood shades, and aniline black.

"4. Sulphur dioxide proceeding from the combustion of coal and coal gas, the quantity of which in towns in considerable, necessarily destroys the ozone of the air. This may account for the definite variations of the proportion of ozone observed at various localities.

"5. In anti-cyclonic periods the amount of sulphur dioxide rises considerably, and at such times this increase is accompanied by at least as large an increase in the amount of organic impurities."

Where there is much soft coal consumed in a certain district the brick and stone become coated with particles of carbon. This

FIG. 196.

The tall chimney in another State is constantly discharging poisonous fumes, resulting from the copper refining process. The chimney was built 365 feet high to obviate the works becoming a nuisance. Atmospheric conditions at times, however, prevent its accomplishing the main purpose of dilution.

deposit causes marble and other light-colored materials to take on a funereal aspect, and not only that, it causes some stone to decay. St. Paul's Cathedral in London is a notable example of this, as shown by Church. In other cases the sulphur gases attack the mortar or cement. This is due to the fact that sulphur dioxide accumulates on the soot and other solids, where it is oxidized to sulphuric acid.

In the manufacture of sulphuric acid used for purifying crude oil and for other purposes, the escape of sulphurous acid fumes from the exits often constitutes a decided nuisance. Not

only is vegetation injured and often killed in nearby sections, but the health of the residents in the neighborhood is injuriously affected by breathing the poisonous vapors, throat troubles of a chronic nature often resulting. However, injuries are often attributed to sulphuric acid factories, when in fact they are innocent. Compliance with the requirements of the English Alkali Act of Lord Derby effectually prevents any serious in-

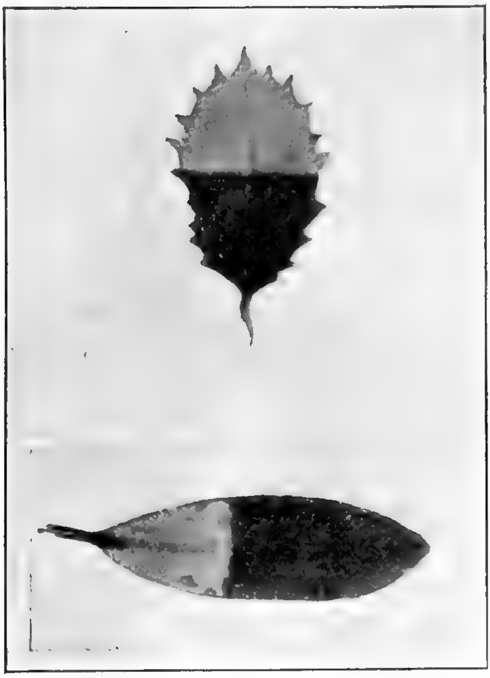

FIG. 197.
Photographs of leaves, showing deposit of soot half removed. These leaves were gathered near Leeds, England. It may be readily conceived just what the effect of the black deposit upon leaves is when we consider that it excludes the light.

jury. Temporary discomfort and even serious injury may result, however, through an accident in the works. Manufacturers wish to avoid accidents and also prevent the escape of sulphur dioxide, for all that is lost diminishes profits. Corrective devices are applied by the works' owners.

In the process of copper refining, smoke is given off from the chimneys and ventilators which contains copper, arsenic, sulphur

dioxide and trioxide, and other poisonous matters. Not only do the fumes injure the health of people who breathe them, but the resulting dust settles on trees, shrubs and plants, often causing them to shrivel up and die. The nuisance from a plant of this sort near New York is much alleviated by a very high chimney erected for this reason.

In 1907, the residents of Staten Island, as well as some on Long Island, complained of the noxious nature of the air wafted over from various plants in New Jersey. This induced the Department of Health of the City of New York to investigate the air and vegetation in the vicinity of the Borough of Richmond, Staten Island, and some of the results obtained are given below, by permission of the Department:

Substance.	Impurity.
Air	Trace of sulphuric acid.
Air	0.0066 per cent. SO_3 by weight.
Air	Trace of sulphuric acid.
Grass (three samples)	Sulphuric acid present.
Grass	0.24 per cent. SO_3.
Grass	0.70 per cent. SO_3.
Leaves	0.19 per cent. SO_3.
Leaves	0.28 per cent. SO_3.
Soil	0.0015 per cent. SO_3.

These results do not really give us anything definite, as the comparative factor is absent. The injury to vegetation resulting from the action of poisonous gases is dependent upon their concentration and not the total quantity. The amounts emitted in New York, Pittsburg, Cleveland, Denver, and Manchester, England, reach astounding figures. Young vegetation is no doubt injured, but it becomes in a measure immune to comparatively small amounts of toxic gases in the air and thrives when well fertilized.

Particles of carbon deposited from smoke on leaves of trees and on various plants impede their respiration by closing the pores and often cause their death. This injury to vegetation is aided by the action of the sulphurous acid contained in smoke. However, in some cases, the injury through atmospheric influence resembles smoke-injury. A lack of iron and the ravages of insects produce yellow or red blotches on leaves. A distinction from fume-poisoning can be discovered, however, by transverse sections under the microscope, when mycelium strings will be observed between the cells. In the case of pines, stronger trees

absorb less than the weaker ones, and even though there is no visible injury, as observed in the change in the appearance of the needles, a microscopical examination will demonstrate that the chlorophyll substance has undergone changes. Poor soil, exposure to wind, especially dry wind, diminished water supply, and fungi, all produce morphological conditions in vegetation which lead to the gravest misapprehensions, and ofttimes accusation of fumes and gases as the cause results, either wrongfully or on *a priori* grounds. Ordinary testimony based upon odor alone should, as a rule, carry little weight.

There are various minor phases of the smoke nuisance in New York which might be briefly considered.

Perhaps the smoke nuisance most frequently discussed in the newspapers is that caused by the more or less imperfect combustion of tobacco. The extent of the nuisance varies according to the time, the place and the person in range, and according to the nature of the fuel, whether it be a Turkish cigarette, an ancient clay pipe, an imported perfecto or a domestic imperfecto. Often what would pass unnoticed in the outside air, could cause a decided nuisance to some people in an enclosed place, such as the subway; and while tobacco is said to be the best barometer of health for the smoker, to others it may cause a decided annoyance. It is perhaps the only form of smoke nuisance which is often quite as effective after the fire is extinguished.*

The nuisance from smoking automobiles on the streets is one that is difficult to entirely prevent. The law is quite specific, but inspectors must be constantly on the lookout for violators of the ordinance.

Smoke is defined, in a less strict sense, as any substance having the appearance of smoke proper, as fumes from burning metals, aqueous vapors, steam or any similar exhalation.

Steam rising from sewer manholes, chiefly in the lower section of Manhattan, constitutes a nuisance during the colder seasons of the year. The odor is offensive, even if the health of the public is not endangered.

One of the worst smoke nuisances about New York during the past few years has been caused by the garbage and other

*Smoking is strictly forbidden in the subways in New York. It is allowed, smoking cars being provided, in the London tubes in which trains move in only one direction in each viacarr, the self-ventilation being so perfect.—(C. B.)

reduction plants at Barren Island. During this process of reduction, oil and grease are extracted from the animal and vegetable matter, leaving a dry residue, which is used as a base for the manufacture of commercial fertilizers, the discarded residue being burned in the plant as fuel.

At another plant at this same point the carcasses of the larger dead animals, which are transported by a regular line of boats, are burned. When the immense number of carcasses ordered removed annually by the New York Department of Health is taken into account, it is not surprising that the smoke given off with the accompanying odors should give offense to residents for miles around. The number removed during the past year included 19,000 horses and about 380,000 dogs and cats, besides about 1,000,000 pounds of condemned meat, about 80,000 pounds of "too gamey" poultry, about 3,500,000 pounds of fish and about 5,000,000 pounds of offal.*

In the manufacture of illuminating gas the by-products are so valuable that the question of saving them is an important one and the smoke nuisance arising from gas plants is not serious. The vapors given off containing harmful impurities are condensed, and tar and water removed. In the subsequent purification, the gas is freed of carbonic acid by means of lime and of sulphureted hydrogen by passing over oxide of iron.†

One of the most extensive industries in this particular metropolitan district is the refining of petroleum.‡ The residual still

*When the Barren Island plants were burned down in 1906, the New York garbage was dumped at sea outside Sandy Hook. An inspection trip made by the writer during the summer of that year showed the bathing beaches on Long Island from Coney Island to Smith's Point and along the New Jersey shore from Seabright to Atlantic City to be literally covered with garbage, which had been driven ashore by wind and currents. If incineration plants for the destruction of various kinds of refuse, including garbage, ashes, rubbish and street sweepings, are imperfectly designed or operated, they are apt to give off objectionable odors and dust with the smoke and become a nuisance, if located near habitations (*vide* Chapter XV).

In New York, a greater part of the ashes, rubbish and street-sweepings is carried by scows to Riker's Island and used for land fills. The odors arising from such deposits often give rise to a local nuisance.

The question is often asked if it would not be profitable to save the street-sweepings of New York and use them for fertilizing purposes. As a matter of fact, even the better grade of street-sweepings has only about half the fertilizing value of stable manure and the cost of delivery of the latter to farmers is now so great as to leave a very small margin of profit, so that the advantageous disposal of street-sweepings in this way is impracticable (*vide* Chapters XVI and XVII).

†Although about thirty billion cubic feet of gas are burned in New York in a year, the sulphur is so well removed that less than one ton of sulphuric acid is distributed per day in the air by its combustion.

‡The first step in the refining process is the distillation, which is done in large cylindrical stills connected with a coil of wrought iron pipe submerged in a tank of water for cooling. The first products of distillation are uncondensed gases. Soon the vapors begin to condense as gasoline, naphtha and benzine. As

tar is drawn off into closed tanks and mixed with coal-dust for fuel. The still is then cleaned by blowing in steam. The offensive gases given off are consumed without causing any extensive nuisance.

Defective stoking in the refineries often results in the production of immense volumes of black smoke, which could be prevented by taking care to add none of the refuse tar and coke until the fire is well started.

It has been suggested that the production of fuel gas at the collieries and its transmission to the various centers for combustion will solve the smoke problem by elimination. However, we are at present dependent upon local installations for the minimization of this unnecessary evil; but a realization of numerous rational changes in methods of generating heat and power is necessarily near at hand, for we are just "awakening to a conscience of the fuel value of smoke."

At the conference on smoke abatement held in London in 1905, Lodge suggested two methods for smoke abatement: the burning of coal at the mines to produce gas or electricity for transmission to cities, and the electrification of the air on a large scale (Rayleigh).

Where bituminous coal is used, alterations in the furnaces and boilers have prevented the discharges from the chimneys from becoming a nuisance.

Of course there are times when a nuisance does occur because of a deficiency of the supply of hard coal, or because of a breakdown in the devices for preventing the nuisance, but these occasions are infrequent and as a rule of short duration. During the great coal strike of 1902, the use of soft coal in New York became quite general, as a matter of necessity. The air of

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the distillation proceeds the products become heavier and when a certain specific gravity is reached the stream of distillate is turned into the kerosene tank. As the gravity becomes higher, common lubricating oil and later paraffine are given off. The distillation is continued until only tar or stillcoke remains.

The escape of light hydrocarbons produced during the first part of the distillation is prevented by a system of hoods and suction conduits, which lead the gases from each still down into its own fire, thereby burning them without offense. The crude oil is run into tanks and exposed to the air in order to receive the bleaching and purifying effect of sunlight and wind. Some odor results from this process. After the last distillate has run off into the heavy oil tanks, there remains in the still tar and soft coke. The various impurities are then removed from the crude distillate by agitating in lead-lined tanks with sulphuric acid. The resulting acid sludge is then drawn off and the oil is washed with water and an alkali and is ready for the market. The disposal of this offensive acid sludge may give rise to a decided nuisance. Some of the refineries carry it away from the cities in sealed tank-boats, without producing any appreciable nuisance. If it is burned, there is apt to be a production of offensive smoke.

the city resembled for a while that of London, the resemblance being carried out even in the matter of fogs of lesser intensity, which consisted almost entirely of smoke. Under certain atmospheric conditions the smoke is collected and a fog results. The fog particles become coated with oily hydrocarbons, which are with difficulty evaporated by the sun's rays. At the time of the coal strike, it was a common sight to see the elevated trains passing up and down through the streets drawn by engines pouring out immense volumes of black smoke. What a difference at the present time with the electrical equipment!

Good firing is admittedly an important factor in smoke prevention, and it has even been regarded as the main factor of the problem*; but many authorities favor the distribution of gas as a means of at least alleviating the smoke nuisance.†

There have been many complaints against some of the railroads running out of New York because of the nuisance caused by their use of soft coal. Some of the suburban towns have taken legal action to prevent this. The solution of the smoke problem on the railroad reduces itself to the use of hard coal or oil, as the application of mechanical stokers to locomotive engines has not proved to be a success; or better still, in electrification. The last is proceeding with gratifying speed.

The theory of Rayleigh‡ for dispelling fog, and with it smoke, by electrification is interesting and is demonstrable in a beautiful way on a laboratory scale, but the expense entailed and practical difficulties involved preclude its favorable consideration.§

*Caborne, *Jour. Roy. San. Inst.*, 27, p. 142.

†For example, Lodge, Des Voeux, A. J. Martin, and A. S. E. Ackermann. In this connection, see *Jour. Roy. San. Inst.*, 27, pp. 42, 64, 80, 85.

‡*Jour. Roy. San. Inst.*, 27, p. 42, and *Elec. Rev.*, 47, p. 811.

§As this is going through the press, reports come that this principle is being successfully applied to fumes in some of the large smelters in the Pacific states.—C. B.

CHAPTER XXII

VENTILATION.

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Associate Professor of Chemistry, College of the City of New York.

Despite the tendency, which is very general, to make light of the problem of ventilation it is a serious matter only too little understood by the masses, and, if understood, receives, except perhaps in the more modern better class public buildings, too little attention. We, none of us, would tolerate dirty floors, draperies, clothes or persons, and yet how many of us do tolerate an atmosphere which is even more foul than the unclean conditions that we can see and therefore remedy.

Recognizing the importance of proper ventilation to prevent disease and the breathing of fresh air, the Tuberculosis Committee begin their "Fundamental Principles" with: (1) "Fresh Air is as necessary to health as pure and nourishing food." In fact, it may be said to be of more importance.

It is estimated that one-tenth of the civilized world die from tuberculosis. The *Journal of the American Medical Association* for 1905 states that every year 110,000 die from this disease in the United States. Of these 110,000 there is one who dies every three minutes right here in New York City, making 10,000 a year, or one out of every seven in the death rate. Is not this matter of ventilation, then, deserving of more attention than it receives?

The Tuberculosis Committee says: "You or some of your family or some friend may be the next victim. Prevent this before it is too late."

Dirt and impure air are the allies of consumption. As precautions are necessary to insure cleanliness and pure air, every individual should be concerned with the perfecting of ventilation and the consequent reduction of indisposition and sickness. Poor ventilation gives rise to a high percentage of gases and vapors which cause headache, stupor, restlessness, a craving for excite-

ment, and also fainting and nausea. Poor ventilation also lowers the vitality of the human body and reduces its powers of resistance to deleterious germs which thrive in these very conditions of neglect of proper sanitation.

The most important of the gases which cause the above ill effects is the carbon dioxide which is exhaled from the lungs or is a product of the combustion of gases or fuel in a room. About 7,000 to 12,000 liters of air pass daily through the lungs. As is generally known, the inhaled air is rich in the life-sustaining oxygen and the exhaled air is laden with the deleterious carbon

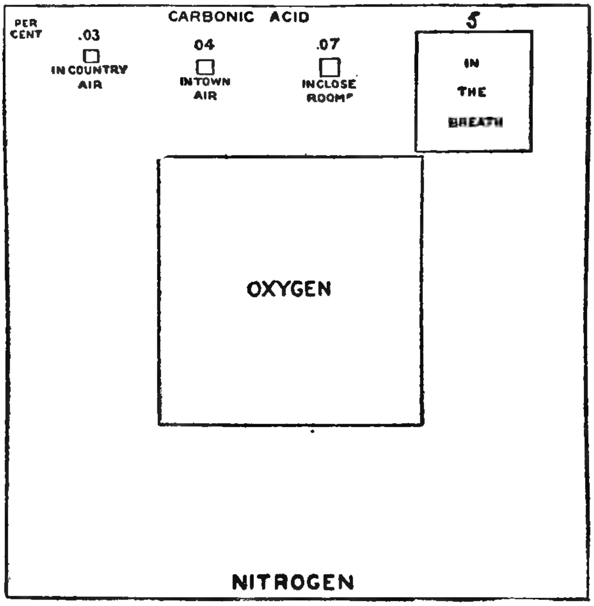

FIG. 198.—A GRAPHIC REPRESENTATION OF THE CONSTITUENTS OF AIR BEFORE AND AFTER BREATHING.

dioxide. Quantitative tests show that one exhales about 450 liters of carbon dioxide daily. The weight of oxygen absorbed each day by every individual is greater than the weight of food he eats. It is not true, however, in the case of air breathed, as it is in the case of food eaten, that provision is made by nature for its purification before absorption.

The decrease of oxygen and increase of carbon dioxide in the breathed air are due to the union of the oxygen of the air

breathed with the carbon of the used material of the body to form carbon dioxide (CO_2).

"Animal heat"* is the result of this oxidation. Lavoisier held that this oxidation—union of the oxygen with the carbon—took place in the lungs themselves, but Pflüger proved that oxygen was carried to the tissues and that the lungs served merely to exchange oxygen for the carbon dioxide. Activity increases this respiratory exchange of oxygen and carbon dioxide. Students having come from another building and having mounted several flights to a lecture were found to give off one part more of carbon dioxide per 10,000 parts than they did half an hour later.† Pettenkofer estimated that according to the degree of exertion 0.006 to 0.012 cubic foot of carbon dioxide was given off per pound of body weight. Inhaled pure air contains about 21 per cent. oxygen and about 0.04 per cent. carbon dioxide. Exhaled air contains 4 per cent. of CO_2 and only 17 per cent. of oxygen. This corresponds closely to the air in which a candle has burned in a confined space and has been extinguished by the products of its own combustion, which is easily shown by experiment.

The carbon dioxide normally present in the air comes from various sources. It is brought up through the earth in air and water. Carbonates decompose on or in the earth's crust to form this gas, vegetable matter decays or oxidizes to carbon dioxide, and furthermore this gas passes into the outside air from buildings, where it is produced from two entirely different sources: (a) oxidation in the air, as in the case of a burning lamp or candle, and (b) oxidation in the human body. Wherever human beings or animals breathe in a confined space, wherever gas or lamps are burned, wherever there is improper chimney connections for heating appliances, as is especially the case with portable gas stoves or in gas radiators which stand out in a room, there will be found large amounts of carbon dioxide. Carpenter‡ gives the per cent. of carbon dioxide (CO_2) in the air in the following places:

London parks	0.0301	In workshops	0.3
On the Thames	0.043	In theatres	0.32
London streets	0.038	Cornwall mines	2.5
Manchester fogs	0.0679		

*Lavoisier and La Place.
†Data from Mass. Inst. of Technology: Richards and Woodman.
‡"Heating and Ventilation," p. 24.

A variation in the amounts of carbon dioxide in enclosed air is found to cover a range of from 0.2 to 0.9 per cent. This is illustrated in the following table:*

A schoolroom in England	0.241%
Sitting-room in a private house	0.304
Public library	0.206
Courthouse gallery	0.290
Printing office	0.149
Tailor's workshop	0.306
Boot and shoe finisher's shop	0.528
Surrey Theatre	0.218
Standard Theatre	0.320
Girls' schoolroom	0.723
Schoolroom in New York City	0.280
Bedroom with closed windows	0.230
Average of 339 experiments in mines	0.785
Sleeping cabin of a canal boat	0.950

While small amounts of carbon dioxide are in themselves not injurious, yet, as it is a substance easily determined, it is generally taken as the index of the quality of air and is the standard by which ventilation is judged. The other deleterious substances are produced generally in the same relative amounts. Ventilation may be considered good when the carbon dioxide does not exceed 0.07 per cent. To one entering from outdoors, air containing 0.08 per cent.—0.09 per cent. seems "close." Continued breathing of air containing over 0.1 per cent. carbon dioxide produces weariness.

Normal air shows no steady increase in carbon dioxide content, as it is constantly removed by vegetation during the process of the formation of cellulose:

$$6CO_2 + 5H_2O = C_6H_{10}O_5 + 6O_2.$$

An acre of forest will absorb a ton of carbon dioxide in a day.

Carbon dioxide is not a true poison, as is carbon monoxide, but if inhaled in sufficiently large quantities it produces death by suffocation. Air containing enough carbon dioxide to extinguish a candle will not cause insensibility. The continuation of the burning of a candle or lamp, therefore, forms a test of safety in breathing a suspected atmosphere. Although one need not fear death while momentarily in such an atmosphere, of course nothing approaching this is permissible for continued respiration. If 0.12 per cent. is reached, discomfort is felt; if there is 0.4 per cent. of CO_2 present, there is actual sensible effort in breath-

*Bailey, in "Sanitary and Applied Chemistry," p. 10.

ing. It is, therefore, generally conceded, at least for sleeping rooms, that 0.1 per cent. is the maximum amount of carbon dioxide consistent with health.

If the inhaled air varies very much from the normal in composition or pressure, the so-called "respiratory exchange," the passage of oxygen into the bodily fluids and of carbon dioxide into the air in the lung cells, is quickly disturbed. The body may adjust itself to these adverse conditions, but the vigor is never as great as when breathing normal air. As the organism accommodates itself to surroundings, the symptoms pass away, leaving

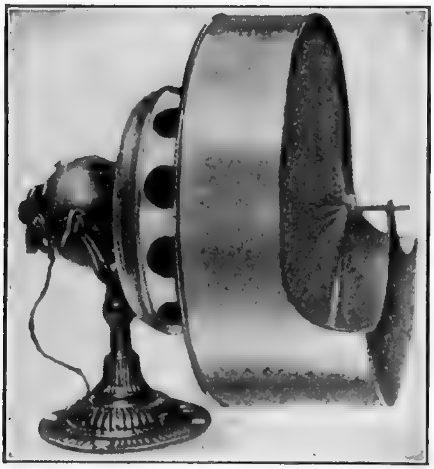

FIG. 199.—ELECTRIC AIR FILTER FOR INDOORS.
The air is thoroughly washed and cleansed by filtration through several thicknesses of wet cotton fabric, whereby it is rendered fresher and much cleaner.

generally a dullness and an irritability, which prevent mental effort or even enjoyment of an entertainment. Everyone has noticed this while working in a public reading room, visiting an art gallery, writing a letter in a post-office, which is almost invariably deplorably without ventilation, seeing a play or attending a service in church.

Increase of carbon dioxide and decrease of oxygen in the air are not the only results of improper conditions for ventilation. An excess of moisture,* increased temperature, dust, and dis-

*For the effect of temperature and moisture, together with odorous substances, see Rousset, "Cosmos," Paris.

agreeable odors, all must be considered as contributing causes to the ill effects; for it has been shown in breweries and in similar works that simply a moderate increase of atmospheric carbon dioxide, even exceeding that in a crowded room, is not productive of these results. Authorities differ as to the special agent which causes discomfort and harm. It is probable, however, that odors, moisture and temperature are all responsible for the disagreeable sensations suffered upon entrance into a polluted atmosphere from fresh air.

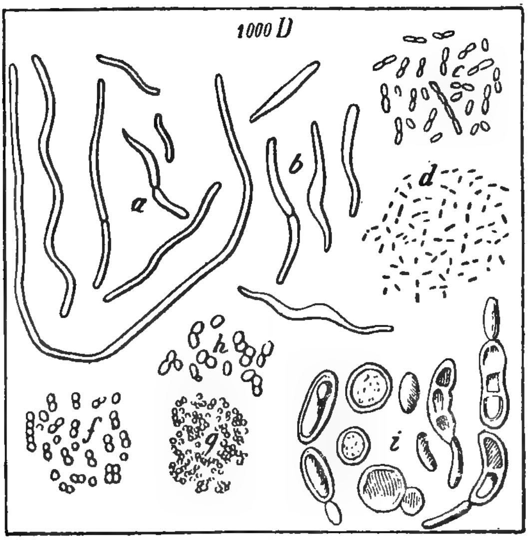

FIG. 200.—ATMOSPHERIC MICROBES (MIQUEL).

The disagreeable odors to which some authorities ascribe the toxic effects are sometimes called "crowd poison" or "miasm." It is the organic matter, carbon dioxide and moisture given off with the breath in addition to bodily exhalations. This theory is upheld by Brown-Sequard and d'Arsonval, who condensed the vapor of newly exhaled air and injected the liquid thus obtained into rabbits, which quickly died. These authorities claim that the vapor must have contained poisonous products, which they say are the cause of the discomfort felt by persons breathing confined air. Such toxins, they claim, are variable and cannot be measured in such small quantities, but that they are

roughly proportional to the amount of carbon dioxide due to respiration which is present. Such matter rapidly changes in character, passing through a fermenting to a putrescent condition. The longer it remains in a room, the worse its odor becomes and the more morbific or disease-producing its condition (Woodbridge). However, Ellen H. Richards (Mass. Inst. of Tech.) has never discovered any toxic substance given off from healthy

FIG. 201.—ATMOSPHERIC MICROBES (MIQUEL).

lungs and her results are substantiated by Dr. Formánek of Prague and Drs. Billings, Mitchell and Bergey in this country. In any case, it cannot be said that such vapors are agreeable even if not positively harmful.

In auditoriums having more than one seating level, the greatest discomfort is felt at the top, for in spite of the greater density, the air is warmer, and hence expands and rises, a difference readily shown by experiments.

The other dangerous agents in impure air—odorless carbon dioxide, insufficient amount of oxygen, and invisible germs—are known only by analysis or by their effects after the damage is done, a damage that should be prevented rather than cured.

Everyone has probably experienced a shock when, looking across a beam of light, he has seen the dust which he is inhaling. When one realizes that dust clouds mean countless germs, the reason is apparent for the warning of the Tuberculosis Committee, "Breathe through the nostrils and not through the mouth." In the open country, for each cubic inch of air there may be 2,000 dust particles; in city streets, 3,000,000; and in inhabited rooms, 30,000,000.*

The attention of the reader is directed to the following table,† which shows the number of colonies of germs obtained in various places after an exposure of twenty-five minutes:

Central Park, dust blowing	49
Union Square	214
In a private house	34
In a dry goods store	199
Broadway and 35th Street	941
When the street was being cleaned	5810
In a house called clean	180
In a filthy house	900
In a dirty school room, natural ventilation	2000
Average in hospitals and dispensatories	127

In the following table‡ the numbers represent the number of germs in a cubic yard of air:

Park of Montsouris	400 to 500
Rue de Rivoli	3000 to 4000
A house on the Rue Morgue	36,000
Hospital of La Pitié	74,000

Carnelly (in Encyc. Brit.) found in mechanically ventilated school-rooms about seventeen organisms per liter of air. When the ventilating fans were stopped, the carbon dioxide at once increased in amount, but the number of germs remained constant. All these germs, of course, are not pathogenic; but as there is a fair chance that many are such, it is just as well to run no chances. By diseased persons no germs are given off in quiet breathing, but they are expelled by coughing, sneezing and expectoration.

*Bailey's "Sanitary and Applied Chemistry."
†Aitken, in *Nature*, vol. 31.
‡Miquel, in "Cosmos," Paris.

So little attention is paid to proper ventilation because the effects are gradual and are not noticed until the harm is done. In many public buildings supposed to accommodate large audiences, no provision is made for ventilation other than opening windows which subject the audience to dangerous draughts.

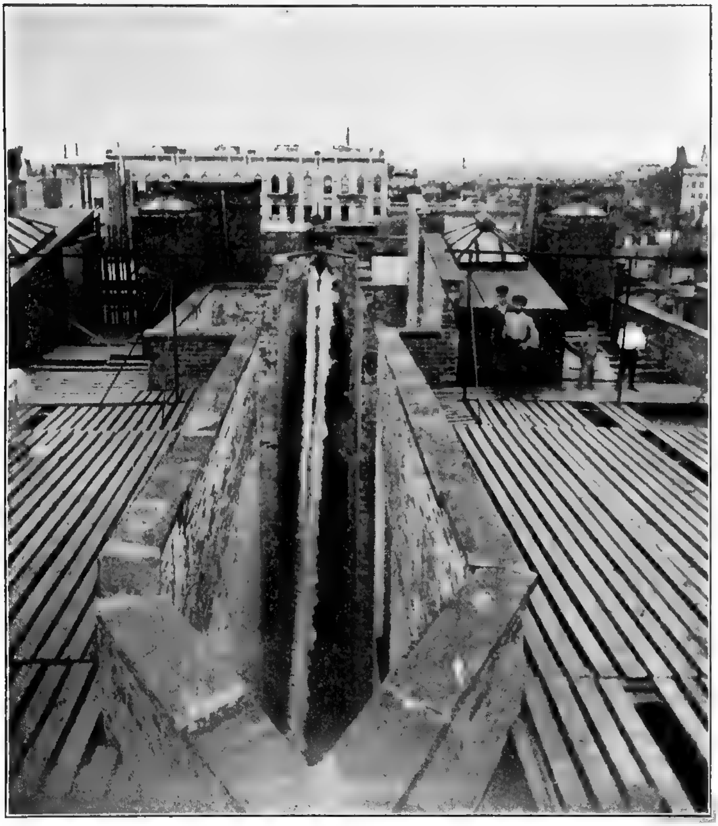

FIG. 202.—A "DUMB-BELL" AIR SHAFT, NEW YORK CITY.

Practically no provision is made in any dwelling except that incident to heating by hot-air furnace, or, in rarer cases, by installing fireplaces in each room. Not only are dwellings usually lacking in special provision for ventilation, but the occupants often fail to avail themselves of that provided by the windows, which, if they are opened, are wrongly or intermittently opened instead of

continuously. Worse still are the wrongly—criminally wrongly—built city tenements, where air cannot be obtained if the tenant wills.

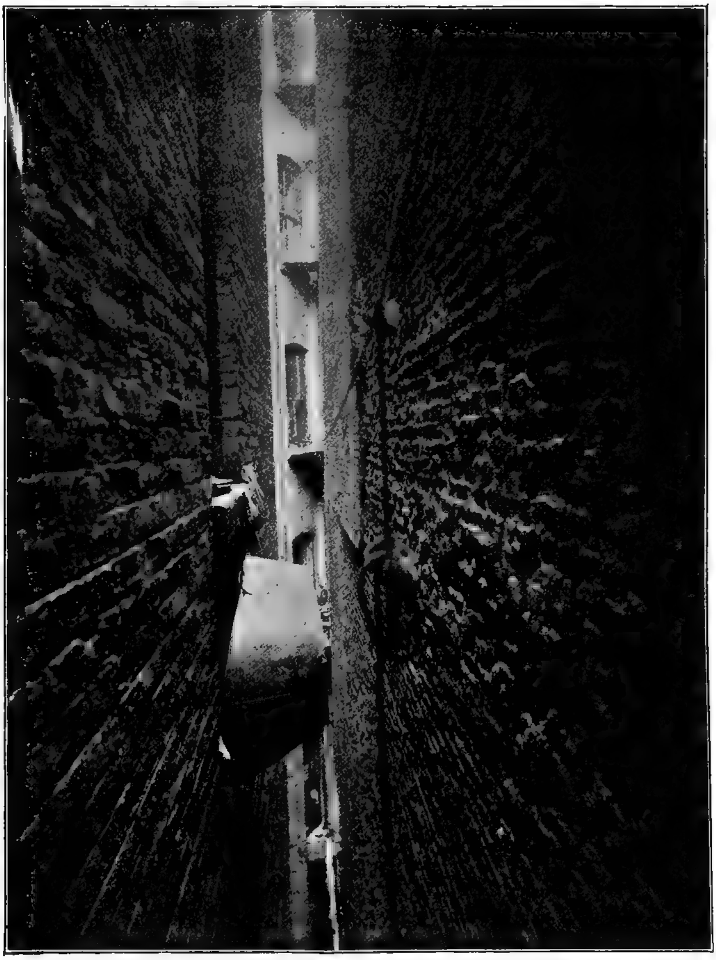

FIG. 203.—INSIDE OF A "DUMB-BELL" SHAFT, NEW YORK CITY.
(Courtesy of the Committee for the Prevention of Tuberculosis, New York City.)

Fortunately this sort of construction is now outlawed in many cities and should be everywhere. The reader is referred to the map of the Tenement House Department, showing the large number of "New Law" tenements built since 1901. These

improved conditions are shown by a canvass of 880 residents of average grade tenements of this city. Of this number, 9 only

FIG. 204.—AN UNVENTILATED "DARK" BEDROOM, NEW YORK CITY. (Courtesy of the Committee for the Prevention of Tuberculosis, New York City.)

FIG. 205.—A LODGING ROOM.
(Courtesy of the Committee for the Prevention of Tuberculosis, New York City.)

slept in rooms having no window, 429 slept in rooms having one

window, 390 slept in rooms having two windows, 37 in rooms

FIG. 206.—A TYPICAL "DARK" ROOM, NEW YORK CITY.
(Courtesy of the Committee for the Prevention of Tuberculosis, New York City.)

FIG. 207.—A "DARK" ROOM IMPROVED BY LETTING IN A WINDOW.
(Courtesy of the Committee for the Prevention of Tuberculosis, New York City.)

having three windows, and 10 slept in rooms with a larger number than three windows.

The present New York City laws are as follows:

1. The hight of the room must not be less than eight feet.

2. The total area of the window or windows shall be at least one-tenth of the superficial area of the room.

3. The top of at least one window shall not be less than seven feet above the floor and the upper half, at least, must open to full width.

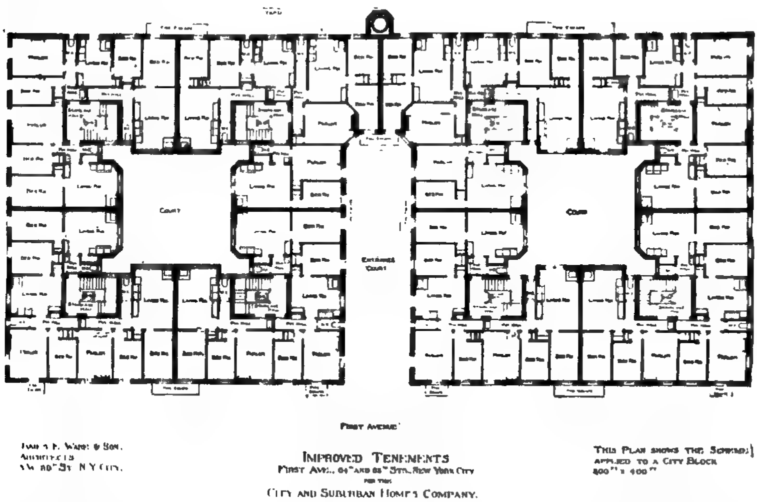

FIG. 208.—FLOOR PLAN OF MODEL TENEMENT HOUSE.
Such are being erected now and rent for prices about the same as the old type formerly allowed in the overcrowded districts.

4. Every room of less than 100 superficial feet, if it does not communicate directly with the outside air and has no open fireplace, must have a special means of ventilation, i. e., a separate shaft to the roof.

In all tenement houses each room must have a window opening to the outside air, as must every water closet.

In Philadelphia it is required that no room shall contain less than 700 cubic feet.

It is considered desirable in this country to furnish in every room from 200 to 300 cubic feet of space per person. Some halls, however, have no more than 100 cubic feet. English laws vary in requiring from 117 cubic feet in schools to 600 in barracks.

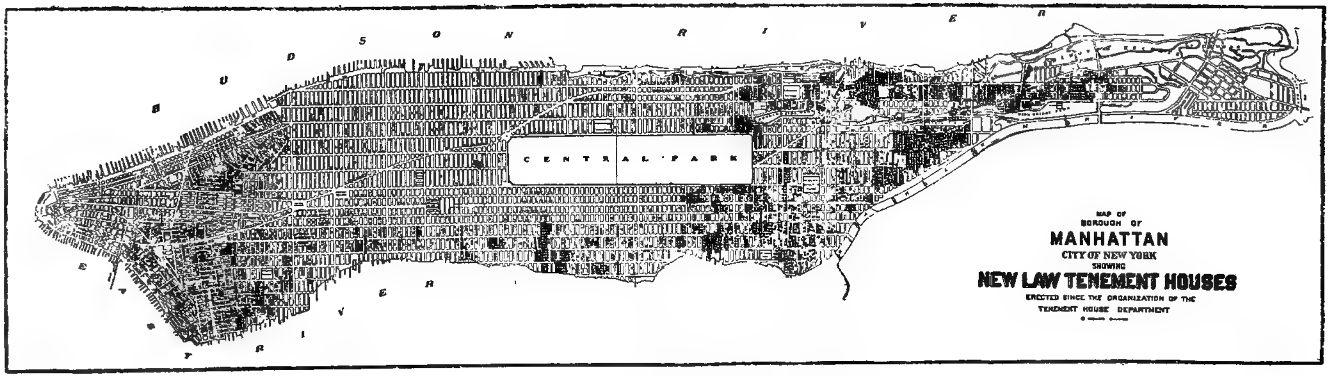

FIG. 209.
(By Courtesy of the Tenement House Commission, New York City.)

Now how can the conditions so far noted be remedied? There will be observed in this table* the amount of pure air needed in various classes of buildings:

	Cu. ft. of air per hour.
Hospitals	3600 per bed
Legislative assembly halls	3600 per seat
Barracks, bedrooms and workshops	3000 per person
Schools and churches	2400 per person
Theaters and audience halls	2000 per seat
Water closets and bath rooms	2400 each
Office rooms	1800 per person
Dining rooms	1800 per person

In the following table† one will find the amounts of air needed per person in order to maintain various standards of purity:

Standard parts of CO_2 in 10,000 parts of air in the room.	Cubic feet of air required per person per hour.
5	8000
6	4000
7	2667
8	2000
9	1600
10	1333
11	1151
12	1000
13	889
14	800
15	727
16	667
18	571
19	500

TO HAVE GOOD VENTILATION THE FOLLOWING CONDITIONS MUST BE FULFILLED:

The air must be—

1. Sufficiently ample in volume to keep the carbon dioxide (CO_2) down to six parts per ten thousand.
2. Free from dust, hence free from germs.
3. Warmed in cold weather.
4. Introduced without draught.

In calculating for the first condition, it must be remembered that the burning of a cubic foot of gas an hour contaminates as much air as a person, so each ordinary gas burner needs as much air as five persons.

Fortunately very few buildings are "hermetically sealed" and therefore ventilation happens to some extent whether one wills it or not. If a man were in an air-tight chamber 12′ x 12′ x 8′,

*Bailey, page 41.

†Carpenter, page 35.

he would reach the limit of purity in thirty-eight minutes. The in-leak, however, through walls and windows is a great deal more than is ordinarily supposed. Experiments (Carpenter) have shown that in an ordinary school house, in ordinary weather, the leakage equals the cubic contents of the room every hour and a half. Windy weather of course increases this. Such leakage only mitigates the evil without curing it. If the leakage is insufficient, the most natural thing suggesting itself is to open the windows. This creates unpleasant draughts, but is effective if properly done. Heated carbon dioxide rises. Some years ago, however, it was the general belief that bad air in a room was at the bottom and would go out at the bottom of the window. Those who have ever mounted a step-ladder in the evening have had ample proof that the hot, bad air is at the ceiling. The proper way to ventilate by a window is to open it both at top and bottom. At the top to let the warmed bad air out and at the bottom to let the fresh air in.

Two other devices primarily intended for other purposes, but which also provide ventilation, are: (1) The fire-place, which is the simplest form of exhaust ventilation when the fire is lighted.* A cold fireplace, however, acts in just the reverse manner and cold air sinks down the chimney and helps confine bad air in the upper part of the room. A cold fire-place, then, does not aid ventilation. (2) The furnace, the simplest means of providing warm, fresh air in a building, is fed with pure out-of-doors air that comes in through a cold-air box. Unfortunately, the "cold-air boxes" are often omitted and cellar air is therefore distributed which may be even worse than the air in the rooms which it displaces. In indirect steam or hot-water systems, the air is warmed under the register just before it enters the room, rather than in a central air chamber at the furnace. This latter system has the advantage that heat can be made to go where it is wanted, a feat often impossible with a hot-air furnace. For public buildings, school houses, etc., large exit ducts must be provided through which the vitiated, warm air may pass out. Such an arrangement constitutes the so-called "gravity" system of ventilation. The area of service and exit ducts must be cal-

*The fire produces in the chimney ascending currents of hot air, which cause the movement of lower layers of air in the room and currents are set up which draw off the higher layers of foul air.

culated for each building. The first should be, roughly speaking, 3-5 sq. ft. and the latter 4-6 sq. ft.

The "blower" or "fan" system (mechanical ventilation) is an elaboration of the indirect heating system, with a central main heater of steam pipes arranged to supply tempered air forced to its destination. This system allows the use of smaller ducts than a "gravity" system. The most widely adopted form is one in which the heating and ventilating are entirely separate, sufficient "direct" radiation being provided to warm the room independently of the warmth of the air supply. The latter is, however, usually "tempered." This modification has the advantage of a minimum of cost, particularly in buildings used intermittently. The rooms are kept warm by direct radiation at all times and the fans need be run only when the building is used.

Still more complete systems make use of pressure blowers, bringing in air at the top of the room, and exhaust fans to remove the vitiated air. The buildings of the College of the City of New York furnish an illustration of this system. Any system of exhaust that does not also force in air (plenum system) tends to draw in untempered air, not only from the regular ducts but from any crack or leak as well, and hence causes unpleasant draughts. Any plenum system (without exhaust as well) will fail of thorough change of air, since the air will leave by cracks, etc., and not necessarily pass out of properly located openings. It is therefore evident that a pressure (plenum) system and an exhaust system combined is the most effective. The supply fan should be of a little larger capacity than the exhaust fan, and thus establish a slight pressure and avoid in-leakage.

Of course in any mechanical system open doors and windows interfere with the prescribed course of the air currents, and complaints under these conditions are unjustified.

It is thus seen that ventilation may be accomplished by natural draught (gravity system) or by forced draught (mechanical system), but, of course, with greater effectiveness when the latter is used. Any ventilating system may be arranged to work upwards or downwards. Both have disadvantages. Upward systems waste heat, as the hot air tends to leave quickly with exits at the top and the floor is likely to be correspondingly cold. Downward systems sometimes fail to start sufficiently rapid

movement towards the exits at the floor, and it is also true that warm exhaled air rises, meets the fresh air from the inlets, and the mixture of these two descends and to a large extent is rebreathed before it reaches the outlets. With the upward system, of course, the exhaled air goes out of the room as soon as it reaches the exit-duct level. The Chemistry Building of the College of the City of New York uses the downward system. In the lecture theatre of that building the air is changed every five minutes. Determinations of CO_2 were made, samples being taken from the middle and four corners, before and at the end of an hour's lecture when the room had been occupied by 250 students. The total CO_2 increased by one part in 10,000. The New York Stock Exchange building has the same system, plus cooling coils, which cool the in-going air to the dew-point. There are arrangements for again warming the air. 3,000,000 cubic feet of air enter the building every hour. On humid days as many as five tons of water have thus been removed from the *air* during the five hours of operation. The downward system has also given satisfaction in far larger buildings; for example, the Chicago Auditorium, which receives 10,000,000 cu. ft. of air an hour and in which the air is completely changed every twelve minutes.

When the downward system is used in theatres the exit ducts in the galleries must have stronger exhaust action than those on the floor, or the foul air from the upper seats will reach the audience in the orchestra.

It is generally agreed that the downward system is effective for rooms from which tobacco smoke is to be cleared. It is less effective in hot, muggy weather.

The system in the German Reichstag is arranged to be made reversible according to conditions.

The downward system, then, is one in which the impurities are diluted, while in the upward system the impurities are at once removed and is really comparable with "flushing with water." If the upward system is used, the ceiling must be kept warmer than the air of the room, otherwise the ascending air will be chilled and descend again instead of passing out of the exits.

The benefits derived from proper ventilation are well shown by the records of the Pension Bureau. When they moved from an ill-ventilated building to one well ventilated, a great decrease

in the sickness of the staff was noted. Formerly in a year the aggregate loss of time had been 18,736 days; in the first year in the new building, with practically the same staff, only 10,114 days were lost—a reduction of 45 per cent. Woodbridge has shown that ventilation systems have reduced mortality in children's hospitals from 44 to 13 per cent.; in army hospitals from 23 to 6 per cent., and in prisons from 80 to 8 per cent. This is also true of animals in an army stable, where a reduction of from 19 to 1.5 per cent. was made.

The human system must have for the chemical action in the body necessary for good health, a generous supply of oxygen. This is provided for in the breathing of pure air. Lacking pure air, the body and brain suffer—in varying degrees—the numerous ill-effects consequent upon impoverished blood or upon the introduction of deleterious germs, ill-effects such as indisposition, brain fag, poor health and disease. It should be the duty of every individual to breathe fresh air day and night. That night air is injurious is an exploded theory. Plenty of oxygen for the combustion of the waste material in the body is an imperative necessity and no individual will be able to live up to the limit of his ability who does not breathe a well-ventilated atmosphere.

CHAPTER XXIII

The Chemistry of Personal Hygiene.

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A discussion of the chemistry of personal hygiene must be developed along two lines. It must take up first the chemistry of the more important physiological processes which we influence or try to influence through personal hygiene. This belongs to physiological chemistry. Second, it must take up the chemistry involved in those procedures of personal hygiene by means of which we attempt to affect the quality of the chemical events which are fundamental to the more important physiological processes. For instance, good digestion is essential to good health. The hydrolysis of proteids, fats and carbohydrates by means of various ferments is a group of chemical processes fundamental to digestion. The physiological chemistry of enzymes then belongs to our first line of discussion. Then the action of these enzymes is affected by the nature, purity and preparation of the food, by habits of eating, by worry, by anger, exercise and so on. The chemistry involved in these considerations belongs to our second line of discussion.

The divisions of physiological chemistry which belong to this discussion become evident when we consider the scope of personal hygiene.

Any well-planned scheme of personal hygiene today must be developed along several distinct but closely related lines. The man that plans such a scheme must regulate his bodily nourishment, including food, water and oxygen, according to known physiological laws; he must attend to his excretions and wastes by way of the bowels, kidneys, skin, lungs, and expectorations according to such laws; he must exercise his muscles with intelligent respect for the laws of the physiology of exercise; he must rest wisely in obedience to his physiological needs; and he must protect his physiological activities from the various agents and

carriers of disease that are known to be injurious or destructive to normal physiological activity.

An intelligent knowledge of these physiological activities depends upon a knowledge of the physiology of the cell. The physical basis of the human body is the protoplasmic cell. Aggregations of cells form tissues, and combinations of tissues form organs. The human body is made up of organs. The health of the tissues, the functional activity of the organs, the health of the body, depend upon the health of the millions of cells which together form the tissues and organs of the body. Each cell must be supplied with food, water, salts and oxygen. Each cell must be exercised in its own specialized way. Each cell must have its proper rest. Each cell must be relieved of the detrimental influences of its own excretions and wastes. And each cell must be protected from the various agents and carriers of disease. The hygiene of the whole body is the hygiene of the cell magnified.

It follows, then, that the chemistry and physics of the protoplasmic cell are the chemistry and physics of the human body. The chemical and physical laws which regulate the nourishment of the cell are the laws which regulate the nourishment of the body. Cell exercise, cell rest, cell excretion and cell protection are under the dominion of chemical and physical laws that operate for the body as a whole.

From this brief introduction it is evident that one can logically discuss this subject under the following headings: (1) The Chemistry of Nourishment; (2) The Chemistry of Excretion; (3) The Chemistry of Exercise; (4) The Chemistry of Rest; and (5) The Chemistry of Physiological Protection.

1.—The Chemistry of Nourishment.—The semi-solid protoplasm of the tissue cell receives its nourishment from the blood stream. In order to meet the wants of the cell the blood must contain dissolved foods, the products of proteid, fat and carbohydrate digestion; dissolved salts; water and oxygen; and in order to be utilized by the cell this material must pass from the blood through the intervening vascular and cellular walls into the cellular protoplasm. We eat, we drink and we breathe in order to supply the blood with the various materials which are indispensable to the life and health of the cell. We are, then,

interested here in the chemistry involved in supplying the cell with the food, water, salts and oxygen brought to it by the blood and received by it through its various intervening membranes.

The food we eat must be chewed, swallowed, digested, absorbed into the blood stream, transported to the cells of the body, and received by the cell through the membrane or membranes lying between its vital protoplasm and the blood stream. The known chemical and physical processes involved in this transaction, by the way of the alimentary tract, are the processes of trituration, digestion, filtration, osmosis and diffusion.

We triturate our food by chewing it. This is analogous to the preparation of chemical bodies in the mortar of the chemist.

The finely divided and ground up food is digested in the stomach and small intestine. Digestion is a chemical process which prepares food for absorption through the intestinal wall. This is accomplished by breaking up the more complex food molecules into simpler soluble products which are more capable of filtration, diffusion and osmosis through the intestinal wall.

Osmosis and diffusion are two very important physical processes utilized in the chemistry of the human body. Partly by means of these processes the digested foods are taken through the intestinal walls into the blood stream. The same processes assist the various cells to draw from the blood the various chemical bodies essential to their vitality and to their peculiar specialized functional activities. By osmosis and diffusion the muscle cell draws chemical bodies from the blood with which it builds up its own curious complex structure and out of which it manufactures that mysterious something which enables it to exhibit the phenomena of contraction; the nerve cell from the same source and by the same processes draws supplies with which it builds its curious and complex structure totally different from that of the muscle cell, and with which it also manufactures certain chemical bodies which, in action, express themselves as voluntary impulses or sensations of touch, of pleasure, pain, heat or cold.

Thus the cells of the body depend upon the blood for food which it brings from the alimentary tract. In addition, they depend upon the blood for food which it brings from the lungs. It is not conventional to regard respiration as a method of taking

food into the tissues, but it is, nevertheless, true that one great object of respiration is to supply the tissue cells with oxygen, and oxygen is a tissue food.

The air we inhale is brought into intimate contact with the epithelium lining the minute air spaces of the lungs. This epithelial lining is a very thin membrane separating the air in the lungs from the blood stream. The oxygen in the air of the lungs passes through this membrane and into the blood stream under the influence of certain physical laws which are known as the laws of partial pressure of gases. Once in the blood stream the oxygen enters into a loose chemical combination with the hemoglobin of the red cells, or is dissolved in the plasma, and is carried all over the body to each of the millions of protoplasmic cells to whose existence it is indispensable.

That part of the chemistry of personal hygiene which refers to bodily nourishment, then, must include the chemistry of alimentation and respiration, and is concerned with (1) trituration, (2) enzyme or ferment action (digestion), (3) the hormones, (4) absorption, (5) the chemistry of respiration, (6) the chemical influences that operate upon the circulating food, and (7) the chemistry of the tissue cell.

(1) *Trituration.*—There are processes which are more or less mechanical that are involved in the preparation of food by various organs of the alimentary canal for the action of the digestive ferments and for absorption which may be regarded as physical measures employed for the purpose of preparing for and expediting the later chemical and physical occurrences. Thus, in mastication food is ground into fine particles so that it is more easily mixed with and attacked by the digestive ferments. The movements of the lower segment of the stomach are for the same purpose. The curious movements of the small intestine, described so well by Cannon, are for the purpose of mixing the fluid chyme with the juices of the intestinal canal, and for the promotion of the absorption of the digested foods in solution.

(2) *Ferments or Enzymes.*—"An enzyme is a substance produced by living cells which acts by catalysis. The enzyme itself remains unchanged in the process and it acts specifically—that is, each enzyme exerts its activity only upon substances whose

molecules have a certain definite structural and stereochemical arrangement. The enzymes of the body are organic substances of a colloid structure whose chemical composition is unknown."*

There are a number of enzymes concerned in digestion. We have (*a*) the proteolytic or proteid-splitting enzymes, such as pepsin in the gastric juice and trypsin in the pancreatic juice; (*b*) the amylolytic or starch-splitting enzymes, such as ptyalin of the saliva and amylopsin of the pancreatic juice; (*c*) lipolytic or fat-splitting enzymes, such as the lipase of the pancreatic juice; and (*d*) sugar-splitting enzymes. There are two groups of this last-named enzyme. One group, called the inverting enzymes, converts the double sugars or disaccharids into monosaccharids. The other group splits up the monosaccharids, but is not a digestive ferment.

These enzymes are all products of cellular action. They are chemical products of unknown composition. They all act by hydrolysis, that is, they cause the molecules of the substance to undergo decomposition or cleavage by a reaction with water.

The chemical action of these digestive ferments may be hastily outlined as follows:

Ptyalin, acting on starchy foods stored temporarily in the fundus of the stomach, changes the starch into maltose and some form of dextrin. The action of amylopsin in the pancreatic secretion is the same as ptyalin. These products are further acted upon in the small intestine by the inverting enzymes; maltose is converted into simple sugar, dextrose, which is more easily absorbed.

The proteolytic enzymes are pepsin and trypsin. Pepsin acts in the stomach in conjunction with hydrochloric acid. Its action is by hydrolysis, and results in the formation and in sequence of acid albumen, primary proteoses, secondary proteoses and peptones. These various products are further split up by the trypsin in the alkaline secretion of the pancreas into such end-products as tyrosin, leucin, aspartic acid, glutaminic acid, tryptophan, lysin, arginin and histidin. The various products of trypsin digestion are absorbed through the intestinal wall, and are acted upon in one way or another by the tissues of the intestinal walls so that these products of tryptic digestion appear in the

*Oppenheimer, quoted by Howell, p. 682.

blood stream in an altered condition. We do not understand the nature of this last action. All we know is that something happens during the absorption of the products of tryptic digestion which changes those products so that none of them appears in the blood or lymph in the form in which it is found in the lumen of the gut.

The lipolytic enzymes facilitate the digestion of fats, which is accomplished by lipase (steapsin) secreted by the pancreas. This enzyme hydrolyzes or saponifies the neutral fats, splitting them into glycerin and fatty acid. These products are absorbed.

(3) *Hormones.*—We have a great deal of evidence that one organ may control the activity of another by means of a specific chemical substance given off to the blood. We call these substances "hormones." Their study constitutes one of the most remarkable of the recent advances in physiology.

"Hydrochloric acid formed in the stomach and brought into the intestine with the chyme stimulates the epithelial cells of the intestine to form secretin and to pass it into the blood. The secretin conveyed by the blood to the pancreas stimulates this organ to secrete pancreatic juice (which contains trypsinogen). The pancreatic juice is carried to the duodenum and stimulates the epithelial cells to form enterokinase, which then activates the trypsinogen into trypsin." This is " . . . . an excellent example of chemical co-ordination, that is to say, of co-ordination effected by chemical stimuli conveyed from one organ to another through the liquids of the body." *

(4) *Absorption.*—Absorption is accomplished largely by diffusion, dialysis, osmosis and filtration. When two miscible liquids or solutions are brought into contact, a homogeneous mixture of the two is soon obtained. This interpenetration of miscible liquids or solutions is called diffusion, and is due to the continual movements of the molecules of the liquids within the confining space. If the two liquids happen to be separated by a membrane, diffusion will still occur provided the membrane is permeable to the liquid molecules. Two liquids separated by an intervening membrane and originally unlike in composition may finally, by the act of diffusion, come to have the same

*Howell, *Science*, January 21, 1910.

composition. Diffusion of this kind is frequently called osmosis or dialysis.

The osmotic pressure varies with the amount of the substance in solution; that is, it is proportional to the concentration of the solution or to the number of molecules (and ions) of the crystalloids in solution.* Osmosis, medically, is a term now used with reference to the passage of water molecules through a membrane; dialysis or diffusion is used with reference to the passage of the molecules of substances in solution through the membrane. Filtration is a term we apply to the passage of liquid molecules under pressure through a permeable membrane or other solid medium. In the intestinal canal the water and liquid molecules of the digested fats, carbohydrates, and proteids, and the salts in solution are absorbed through the walls of the gut more or less under the influence of these laws.

(5) *The Chemistry of Respiration.*—Gaseous exchanges in the lungs and tissues occur in conformity with the law of partial tension regulating the diffusion of gases. "If a permeable membrane separates two volumes of any gas or two solutions of any gas at different pressures, the molecules of the gas will pass through the membrane in both directions until the pressure is equal on both sides." (Howell.)

The weight of experimental evidence makes it appear that the partial pressure of oxygen in the alveolar spaces of the lungs is greater than it is in the blood; that the partial pressure of the oxygen in the blood is greater than it is in the tissue cells. The law of partial pressure of gases would then explain the diffusion of oxygen through the lung membrane to the blood and from the blood to the tissues. This is a fairly rapid process. The blood loses its oxygen to the tissues at the rate of 35 per cent. of its oxygen content per second. (Howell.)

The oxygen in the blood is in great part combined with the hemoglobin of the red cells from which it is easily dissociated; a smaller portion is in solution in the plasma.

(6) *Chemistry of Circulating Foods.*—The foods present in the circulating fluids of the body may be itemized as follows: (*a*) proteid; (*b*) fat in emulsion; (*c*) sugar; (*d*) dissolved

*According to Kahlenberg, this action is not limited to crystalloids, but applies to colloids as well, and is dependent, among other things, upon the character of the membranes.—C. B.

salts; and (*e*) oxygen in loose combination with hemoglobin and dissolved in the blood plasma. While these foods are circulating they are affected chiefly by the liver. This great gland acts upon the sugar and a part of the proteid and fat in the blood, and changes those bodies into glycogen, and stores this newly formed material in the liver cells. When the glycogen stored in the liver is needed by the tissues, it is converted into sugar again and carried in that form to the tissues.

$$C_6H_{12}O_6 - H_2O = C_6H_{10}O_5 \text{ (Glycogen).}$$
$$C_6H_{10}O_5 + H_2O = C_6H_{12}O_6 \text{ (Dextrose).}$$

It is probable that a part of the nitrogen of the recently absorbed proteid food is without further delay converted into urea by the liver, and then carried by the blood to the kidneys, where it is excreted.

So far as we know of their chemistry, the oxygen, salts and water in the blood are not affected while those foods are in the blood.

The blood distributes its burden of proteid, fat, sugar, salts, oxygen and water to all the tissues of the body. Usually these constituents pass from the blood capillaries to the lymph spaces surrounding the tissue cells and then from these spaces into the cells themselves. This passage through the capillary wall, through the lymph space, and through the cell membrane, is accompanied by diffusion, osmosis and filtration. Yet these physical phenomena are not sufficient to explain the passage entirely. The known laws of filtration, osmosis and diffusion, do not explain completely the passage of food in solution from the blood current to the cell protoplasm.

(7) *The Chemistry of the Tissue Cell.*—The chemical reactions which occur in the functionating tissue cell are not understood. We know that the blood brings to the cells proteid (serum albumin), carbohydrate (sugar), emulsified fat, salts, oxygen and water. And we know that the blood carries away from the tissue cells a number of waste products, chiefly CO_2 and the precursors of the various chemical bodies found in the urine, such as urea, creatinin, the purin bodies, etc.

We believe that a certain portion of the proteid food which is not converted into urea by the liver is used by the cell to build up its structure; that the remainder of that proteid food is used

with the other foods by the tissue cell for the elaboration of those cellular chemical bodies which the cell employs in one way or another for exhibition of its functional peculiarities—contraction, secretion, innervation, production of immunity, etc. But we know very little about the synthetic chemical events which produce cellular protoplasm, whether that protoplasm be structural or functional in its physiological mission.

We now believe that the tissue cell uses a part of the protein food brought it by the blood for structural repair; and that the remainder of the protein food, having lost its nitrogen in the liver, may be stored up by the cell as glycogen or fat and subsequently oxidized. The cell acts upon its carbohydrate supply, storing it up until needed, and then oxidizing it into carbon dioxide and water. The blood carries sugar to the tissue cells; an enzyme or hormone furnished by the pancreas enables the cell to utilize the sugar, which is finally oxidized.

The carbohydrate food supplies muscular energy. It supplies heat for the body, through the oxidation of sugar, and it protects the protein of the body. That is to say, less proteid food is used by the tissue cells in the presence than in the absence of carbohydrate food.

The cell uses its supply of fatty food as follows: (*a*) It may oxidize the fat-forming heat energy with CO_2 and H_2O as end products; (*b*) it may store it up for future use as body fat; (*c*) it may synthesize the fat into more complex bodies; and (*d*) it may transform the fat into sugar.

These, then, are the main facts in the chemistry of nourishment. To what extent are these processes under the dominion of a deliberate plan of personal hygiene? The chemistry of personal hygiene must be the chemistry which man can influence through his habits of personal hygiene.

It must be admitted frankly that we are without direct influence upon these processes. But, on the other hand, we have various means of exercising a most profound influence indirectly. We can supply the human chemical laboratory with a good quality of material, such as pure, clean, digestible food, good water and pure air. We can see that these supplies are properly prepared, the food properly cooked and appetizingly

presented. We can supply food, water and air in sufficient quantity.

After looking with care into the quality, quantity and preparation of the supplies that are to be used in the human laboratory, we can influence some of the procedures by means of which these supplies are brought into chemical association with the various reagents of the human laboratory. We can chew our food so that it is well ground up and mixed with saliva. We can eat under quiet and pleasant surroundings, thus permitting the muscular movements of the stomach and intestine to go on without interruption. These muscular movements assist in mixing the food with the digestive ferments, bring it in contact with the absorbing surfaces of the intestine, and force the unused foods and intestinal excretions on and out of the canal. These movements cease if the individual becomes stirred up emotionally. Anger, fright, muscular exertion and mental concentration inhibit these movements.

We assist in the proper secretion of the various digestive enzymes—the reagents of the alimentary canal—by eating appetizing food, by being cheerful at our meals, and by eating slowly. Strong mental or physical activity suppresses these secretions. Rage, fear, mental depression, mental concentration, worry or work prevent or stop the secretion of the digestive hormones and ferments.

Furthermore, we can keep our laboratory equipment in good condition. The human laboratory needs even more care than a college or university laboratory. The man without teeth or with untreated decayed teeth has lost a valuable and essential part of his equipment. The man that suffers from gastric or intestinal indigestion has something wrong with his apparatus which, if not repaired, will do him increasing injury. The child with obstructed air passages may have his laboratory equipment overhauled, and thus escape further, and perhaps irreparable, pulmonary and general systemic injury.

2. Our contention also is that good health depends upon the care we exercise over our EXCRETIONS. The excretions of the body occur chiefly through the kidneys, the lungs, the nose and mouth, the skin and the bowels. Primarily all these excretions are cellular excretions. The kidneys, skin, mucous mem-

branes, lungs and bowels are avenues through which the blood is able to discharge its burden of waste material. We have then to consider excretion from two points of view. First, excretion from the cell into the blood stream, and out of the body through one of these avenues.

In general it may be stated that tissue activity results in wear and tear upon cellular structure and in a destruction of chemical bodies which have been earlier synthesized by the cell. The end products of these chemical reactions are carbon dioxide, water and certain ammonia derivatives which are discharged by the cell into the blood.

The carbon dioxide goes into solution in the blood plasma and also probably enters into some loose chemical association with the blood corpuscles. It escapes from the blood through the thin membranous lining of the lung spaces under the influence of the law of partial pressure of gases to which we referred when considering respiration.

The water excreted from the blood leaves the body by way of the kidneys, the skin, the lungs, the mucous membranes and all fluid secretions. In every case the water leaves the blood by osmosis and probably filtration through a tissue membrane of some sort. These processes have already been described.

The ammonia derivatives in the blood are discharged mostly through the kidneys in the form of urea and associated bodies. The physico-chemical process by means of which the discharge is secured is probably a combination of osmosis, diffusion and filtration.

We have no direct influence upon the chemistry of cellular excretion. We are able, however, to offer mechanical assistance to the removal of wastes from the cell itself. Massage and exercise are effective methods for this purpose. Massage and exercise squeeze the tissue juices into the lymph channels and away from the cells themselves. In addition, a greater amount of blood passes through the exercised muscle than through the resting muscle. The increased venous outflow may be regarded as a process of flushing which clears the wastes out of the tissues.

Our direct influence upon the physics and chemistry concerned in the discharge of excretions from the blood and out

of the body is no greater than our influence upon the physics and chemistry concerned in the discharge of excretions from the cell into the blood. We have, however, a greater indirect influence. We can make ourselves sweat and thus cause the skin to increase its excretion activity. We can exercise our muscles and influence our lungs to remove a greater amount of carbon dioxide. We can drink plenty of water and increase the elimination through the kidneys; we can cultivate habits of regularity in eating, drinking and going to stool which will secure a satisfactory performance of the excretory function of the bowels.

3. EXERCISE is one of the most important of our health habits. By means of exercise we are able to influence the functional activity of the voluntary musculature of the body, the bones and joints, the heart and blood circulation, the lymphatic circulation, the lungs, the skin, the kidneys, by far the greater part of the reflex motor and sensory nervous system, the spinal and cranial nerve centres, and even the psychic centres themselves.

The chemistry of exercise, then, logically includes the chemistry of voluntary muscular contraction and of nerve action, and indirectly the chemistry at the bottom of all the other organic functions just mentioned. The muscular nervous tissue receives from the blood its supply of chemical bodies, the products of proteid, carbohydrate, and fat digestion; the salts of those foods; water, and the oxygen secured from the lungs. Out of this supply the muscles and neurons build up their characteristic framework, so that one is a muscle fibre and the other a neuron. And out of that same supply the muscle, by means of its own methods of synthetic chemistry, manufactures those chemical bodies which, during exercise under the influence of the motor impulse from a neuron, react and cause the muscle fibre to contract; and the neuron, from that same supply, manufactures an entirely different set of chemical bodies, which, by chemical action during exercise, express themselves in motor and other nervous impulses. During exercise the chemical bodies elaborated and stored up by the nerve cell and muscle fibre are broken down. The products of this chemical action appear in

the blood as carbon dioxide, water, sarcolactic acid, creatin, and other less known substances.

We are not able to affect directly the quality of chemical action in exercise, but we can obviously do a great deal to affect the quantity of this chemical action. It is a well-know law of physiology that an unused organ atrophies and that an exercised organ grows. This is probably due to the fact that an exercised organ receives more blood and therefore more nourishment than an organ that is not used. And so, if our other health habits are right, we are able through exercise to increase the synthetic chemical reactions in our muscles and nerves, causing them to grow larger, more efficient and healthier. This beneficial influence is extended to all those other tissues and organs with which the muscles come into intimate or remote physiological relationship.

4. The Chemistry of Rest.—We are relatively at rest when we are not actively working any of our organs. We are really at rest only when we sleep, and there are a number of theories concerning the cause and nature of sleep.

Preyer, in 1875, advanced the theory that sleep was due to the influence of acid wastes in the circulation. These acid wastes were presumed to produce a diminution of irritability in the higher nerve centres sufficient finally to secure unconsciousness. The sarcolactic acid given off by the contracting muscle, or the acid reaction produced by active nerve centres, would lend its help to this theory. Pflüger suggested that the brain cells use up more oxygen during waking hours than they can absorb from the blood, and that sleep is therefore necessary in order that the supply of intra-molecular oxygen in the nerve cells may be replaced. Howell advances the theory that sleep is due to an anemia of the brain, consequent upon the fatigue of the day and the habit of courting sleep in a recumbent position in a dark room or in a quiet and comfortable place. All these influences act to lower the blood pressure, and therefore reduce the blood supply of the brain.

At the bottom of all these theories one finds an emphasis laid upon the influence of the fatigue of the day. This means an emphasis upon the influence of the chemical bodies given off to the blood by the functionating tissue cells. Fatigue is the result of the influence of tissue wastes in the blood due to chemical activ-

ities in the living cells of the body. These wastes are excretions and are held to be more or less poisonous in their influence upon the living cell. We sleep, then, in order to assist the tissues to neutralize, to destroy, or send out of the body these irritating waste products. In addition, we sleep to give the tissue cells opportunity to repair synthetically the losses they have sustained during the waking hours.

5. Protective Chemistry in Personal Hygiene.—First, we protect the body by keeping it clean. The proper use of soap and warm water offers us one of our cheapest and best defences against disease. Bacteria are found everywhere. They live in the creases and pores of the skin, under the nails, in the mouth, nasal passages, fornices of the eyes—in fact, on the walls of all openings from the surface of the body. Some of these bacteria are pathogenic. The warmth, moisture, darkness and uncleanliness of the body offer environmental conditions necessary for bacterial life. Appropriate washing solutions for the more tender mucous surfaces, and hot water and soap for the less sensitive skin, are expedients by means of which we remove some of the bacteria themselves and a part of the food on which they live.

When we bathe we either depend on dissolving unclean material in water or we rely upon the chemical action of soaps in the presence of water upon the sebaceous or fatty accumulations on the surface of the skin and mixed in with the other foreign matter there present and then washing them away.

Second, we protect ourselves from disease by avoiding contact with articles that have become contaminated with disease-breeding organisms. In addition to the necessity for keeping the body clean, we find it advisable to keep those things clean with which the body comes in contact. This cleanliness is not the simple cleanliness that follows washing with water and soap. It is often quite impossible to remove bacterial contaminations that way from infected articles. Under such circumstances we employ agents which destroy the bacteria themselves. We can accomplish this by burning with fire, boiling in water, or saturating with certain fluids or gases. We burn useless articles that have become contaminated. We boil bed linen, sheets, underwear and various other articles made out of cloth. We soak

clothes and various articles that might be injured by fire or by boiling, in such solutions as alcohol, carbolic acid and mercuric chloride. We use formaldehyde gas for the disinfection of the sick room with its fixtures, bedding and so on. The gas is efficient; it penetrates easily, and fills the entire accessible space in the room.

Third, sunshine and fresh air are two agents that defend the human race from disease. In fact, they are the cheapest and most powerful agents at our disposal. The most virulent of our pathogenic bacteria live only a few hours when exposed to sunshine.* Bacteria live and thrive in dark, damp, warm and dirty places. The importance of sunshine and fresh air in the protection of the human race becomes evident when one remembers that a single moderately advanced case of pulmonary tuberculosis may expectorate several billions of *tubercle bacilli* in twenty-four hours, and that there are only a billion and a half of human beings on the globe. The importance of these protective agencies becomes further apparent when we remember that a single bacterium may multiply by binary fission in fifteen minutes. Given the essential conditions, that single bacterium could, within forty-eight hours, increase to the number of 9,544 billions of bacteria, which would weigh 15,000 tons.

We have so far been dealing with some of our external defences against disease. There remains for our consideration our very important internal defence, which we call immunity.

"The production of active immunity is a function of some of the fixed and circulating cells of the body. When pathogenic organisms within certain limits of virulence gain access to the tissues, they are destroyed or rendered innocuous by one or more of several processes. They may be devoured by phagocytes; they may be killed and dissolved by agents in solution in the tissue juices; they may be imprisoned and walled off locally from the rest of the tissues; and their toxic products may be neutralized or destroyed by soluble antibodies in the tissue-fluids. These several defensive activities are carried on directly by the tissue cells or indirectly by the products of the vital activities of

*Drying in the air and light kills all. A few bacteria form spores which resist drying.

those cells. On the cells of the body depends the exhibition of the phenomena of immunity."*

The phagocytes are attracted to the centres of pathogenic attack through chemotaxis. The destruction of the ingested bacterium by the phagocyte is accomplished by the action of ferments within the cell. The destruction of these pathogenic organisms in the blood or lymph is due to the presence of specific chemical bodies, possibly enzymes. The production of connective tissue for the purpose of walling off areas of inflammation is the result of the chemical irritation exercised on the local tissues by the toxic products of bacterial action. The neutralization of these chemical toxic products is accomplished by chemical anti-bodies thrown off by the tissue cells under the irritating influence of bacterial growth. Speculation as to the origin and nature of these protective chemical bodies has given rise to one of the most brilliant and daring hypotheses of modern science, Ehrlich's side chain theory, which offered, among other things, an explanation of the phenomena of immunity. A discussion of that theory may not be undertaken here. It may be said that "the degree of immunity produced is related directly to the health of the cell." An impoverished, poorly nourished, unhealthy cell will not react to the same extent and with the same success as will the normal, healthy, well-nourished cell. The health and, therefore, the immunity-producing power of the cell depends upon its nourishment; upon its relief from the influence of its own waste products; upon its exercise; upon direct and indirect influences of pathogenic organisms. These facts have everywhere been forced upon the attention of men who are experimenting with the immunity reactions of the blood. They find healthy blood is necessary for good reactions. Bactericidal phenomena, phagocytosis, bacteriolysis, agglutination, the production of antitoxins, and the other phenomena of immunity are all more marked in blood taken from healthy animals. It has been found in laboratories everywhere that a reduction in mortality and a more successful experimentation with the vital phenomena of cellular structures in experimental animals accompany the provision of good and sufficient food, exercise and careful sanitation.

*T. A. Storey: "The Promotion of Immunity Through Physical Education," *Proceedings of the Sixth International Congress on Tuberculosis.*

The health and, therefore, the immunity of the whole body depend upon the health of all its constituent parts—on the health of its cells. If the cells are all well nourished, active and protected from extremes of pathogenic influences, their summated health will be the health of the individual, whose body they in combination make. That such a healthy individual is possessed of a certain degree of immunity has been proved empirically and experimentally, and it is equally well established that the possession and conservation of the healthy body depend upon the observance of several simple hygienic procedures. These hygienic procedures are the same as those which have already been stated as essential to the body-cells. Furthermore, these procedures must be the fundamental procedures in any wise and well ordered policy of personal health control.

Physical Education or Personal Hygiene (the terms are here used synonymously) is concerned primarily with human health. It employs the same hygienic procedures for its purposes that are essential for the development of health and consequent immunity-producing powers in the cells of the body. Its principles are based upon the fundamental facts of hygiene. It employs recognized hygienic precepts in the procedures which it lays down for health. The well-planned scheme of physical education of today teaches men to eat properly, to drink properly, to breathe properly, to take proper care of the excretions and wastes, to exercise wisely, to rest wisely, and to keep reasonably clean with reference to disease-breeding organisms. Such governing principles lead to and conserve human health. Failure to respect any one of these principles will jeopardize the success of the others. No rational scheme of physical education nowadays relies upon exercise alone for health, nor upon any other one procedure or habit. One must observe all of these several requisites in order to work under a wise policy of physical education—of personal health control. The man who regulates his habits of eating and takes no exercise cannot expect health. The man who exercises properly and eats wisely will fail to secure health if his habits of sleep are bad. On the other hand, a reasonable observance of these several simple hygienic laws on which physical education is based cannot fail to secure and conserve health for the average individual.

Such an individual will be possessed of millions of active, healthy cellular structures working for his protection, constructing for him a defensive armamentarium, and ready on demand to respond with supreme reaction against invasion of disease.*

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*T. A. Storey: "The Promotion of Immunity Through Physical Education," *Proceedings of the Sixth International Congress on Tuberculosis.*

CHAPTER XXIV

Textile Materials and Their Service to Man.

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The average man is usually more concerned about what he eats and drinks than about what he wears, but with women it is often the reverse. Undoubtedly the average cost per capita of that with which a man covers his body is less than the cost of food he consumes, but, nevertheless, there are certain respects in which the importance of clothing is paramount. Common law has no particular objection to one's traveling about with an empty stomach, but demands that he shall be properly clothed.

According to statistics furnished by the Department of Commerce and Labor, the Textile Industry is only outranked in importance among the industries of the country by two—those of the manufacture of food and kindred products, and of iron and steel and their products. Although the capital invested and the value of the products produced may be greater for the food and iron and steel industries, the number of wage-earners employed in the textile and allied industries is far greater than in either of the others. According to the census of 1905, there were 1,156,305 employed in the production of textile materials and their manufacture into finished products, which was nearly one and one-half per cent. of the total population of the United States at that time. In other words, one person in every seventy the country over, including men, women and children, is engaged in the manufacture of textile products. The growth of the textile industry in the United States during the past half century has been marvelous, the increase during this period having been nearly one thousand per cent.

For convenience the subject may best be considered under the following headings:

(1) The Raw Materials of the Textile Industry.

(2) Processes of Converting these Raw Materials into Textile Fabrics.

(3) The Consumers' Interests and Rights.

(1) *The Raw Materials of the Textile Industry.*

The primary raw materials of the Textile Industry are the so-called textile fibers, but we must not overlook the numerous and secondary materials, such as scouring, bleaching and coloring agents, which contribute no small portion to the cost of the finished product, and without which the possibilities of the textile industry would be extremely limited.

The following classification will give, in a condensed form, a general conception of textile fibers. They may be subdivided according to their origin into two principal classes, *Natural* and *Manufactured,* which in turn may be subdivided as follows:

I.—*The Natural Fibers.*

- (1) VEGETABLE FIBERS:
  - (a) Seed Fibers; cotton.
  - (b) Wood Fibers; chiefly from spruce and poplar, and used in paper making.
  - (c) Stem, Bark or Bast Fibers; Flax (linen), Hemp, Jute and Ramie.
  - (d) Leaf Fibers—Sisal, New Zealand and Manila Hemp,. used chiefly in rope making.
  - (e) Fruit or Nut Fibers; Cocoanut Fiber, used chiefly in making brushes and mats.
- (2) ANIMAL FIBERS:
  - (a) Wool and Hair; Sheeps' Wool, Goats' Wool or Hair, and the hair of such animals as the llama and camel; rabbit hair is extensively used in the manufacture of hats.
  - (b) Silk Fiber; cultivated or tree silk, sometimes called mulberry silk; wild silks.
  - (c) Reclaimed and Extracted Animal Fibers; Shoddy and Mungo.
- (3) MINERAL FIBER:—Asbestos used in the manufacture of fireproof material, particularly theatre curtains.

II.—*Manufactured Fibers.*

(1) ORGANIC FIBERS—Various forms of artificial silk.
(2) MINERAL—Glass and Slag Wools.
(3) METALLIC—Fine Metallic Wires and Tinsel Threads.

Cotton.—Cotton fiber is the white fibrous material which covers the seeds of several species of plants known botanically as *Gossypium,* and growing chiefly in Southern United States, Egypt, India, China and Peru. The seeds to which the fibers are attached are enclosed in a capsule or pod known as a cotton boll,

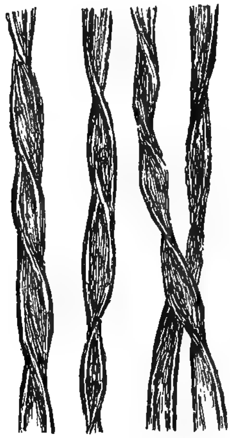

FIG. 210.—COTTON FIBER.

from which, when ripe, the cotton is picked, together with the seed. The cotton is separated from the seed by the process known as ginning and is then ready for shipment to the manufacturers. The cotton seeds were formerly of no value, but during recent years they have become a source of great income, owing to the large amount of oil which may be pressed from them, and the various animal feeding products and fertilizing materials which they furnish.

A typical cotton fiber is well described as a long, tubular, slightly conical vegetable cell varying somewhat in diameter and length, these variations depending chiefly upon the variety. Under the microscope, matured cotton fibers have the appearance of long flattened tubes, thicker at the edges than at the center, and

spirally twisted, thus resembling a twisted ribbon, the edges of which are thick and rounded.

It is this special physical structure of cotton fibers which renders them so suitable for the manufacture of very fine yarns. Their hollow condition makes them light, while their cork-screw-like twist renders them elastic and gives them excellent spinning qualities.

Cotton fibers average between three-quarters and one inch in length. Sea Island and Egyptian cotton fibers may be one and one-half inches in length, but a cotton fiber two inches in length is the exception.

FIG. 211.—MICROPHOTOGRAPH OF COTTON FIBER.

The approximate composition of raw cotton fiber is:

Cellulose	87 to 90 per cent.
Hygroscopic Water...............	5 to 8 per cent.
Natural Impurities...............	4 to 6 per cent.

Cellulose furnishes the non-nitrogenous framework of plant life in general and vegetable fibers in particular, but in cotton fiber it appears in an especially pure form. When the 4 to 6 per cent. of accompanying natural impurities are removed, "absorbent cotton" is produced, which, except for the hygroscopic moisture it contains, is practically pure cellulose.

Linen.—Linen fiber is a bast or stem fiber, obtained from the flax plant. Next to cotton it is the most important of the vegetable fibers. The flax plant grows best in a temperate climate, and is cultivated in nearly every country of Europe, to a considerable extent in the United States and Canada, and to a limited extent in South America. It is herbaceous in character, with long, narrow and smooth leaves, and bears blue flowers, which ripen into the seeds, so valuable for the production of linseed oil.

Whereas cotton is ready for the textile manufacturer immediately after it has been ginned, flax has to undergo a series

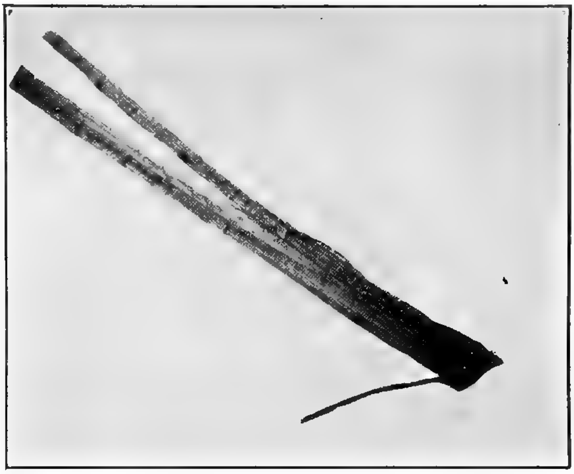

FIG. 212.—MICROPHOTOGRAPH OF FLAX FIBER.

of extensive operations involving both mechanical and chemical principles, before workable linen fiber can be produced. This is necessary because air-dried flax contains less than 30 per cent. of actual linen fiber, the remainder consisting of wood pith and rind which cling to the fiber with such tenacity that the process of separation is rendered difficult. The chief operation of the separating process, known as *retting,* is carried out in a number of different ways, but in every case the object is to decompose by fermentation or otherwise the pulpy and resinous matter that holds together the woody material and actual fiber and thus render the two separable. The other operations, known

as breaking, scutching and hackling, are purely mechanical and have for their object the complete removal of the softened and broken woody material, shive and pulp, so that complete separation of the individual fibers may be accomplished. The two products resulting from these operations are the *flax line,* which consists of the long, straight and most valuable fiber in the paralleled condition, and the *tow,* which consists of the short and poorer fibers in a more or less tangled condition. Flax line has the appearance of a long, fine, soft and lustrous fiber. When examined under the miscroscope, what appeared to the naked eye to be a single fiber, proves to be composed of many smaller fiber cells, which cling tightly to each other. When separated, these ultimate fiber cells are found to be much shorter than the flax line, pointed at the ends, polygonal in cross section, and possessing thick walls and minute central canals.

FIG. 213.—MICROPHOTOGRAPH OF WOOL FIBERS.

Linen fiber differs from cotton fiber in that it is never flattened or twisted. The natural color of linen varies from a pale yellow, through a silver gray to a greenish color, but when bleached it becomes perfectly white. Linen possesses greater strength, but less elasticity, than cotton.

Linen, like cotton, consists for the most part of cellulose, but differs from cotton in that it is accompanied by 15 to 30 per cent. of natural impurities.

Hemp.—Hemp resembles flax in nearly every respect and its treatment is similar. It is, however, much coarser and is seldom bleached or dyed. It is used almost entirely for the manufacture of twine and bagging.

Jute.—Jute is obtained from a plant which is a native of India and the East Indian Islands. It grows much taller than flax, and the fiber is coarser than linen, but in general character it resembles flax and the process of treatment is similar. In chemical composition, however, it differs from linen, and will not withstand the action of water or chemical agents to the same extent as the latter, consequently much care must be taken in its treatment. It is used chiefly in the manufacture of burlap, carpets, draperies and wall hangings.

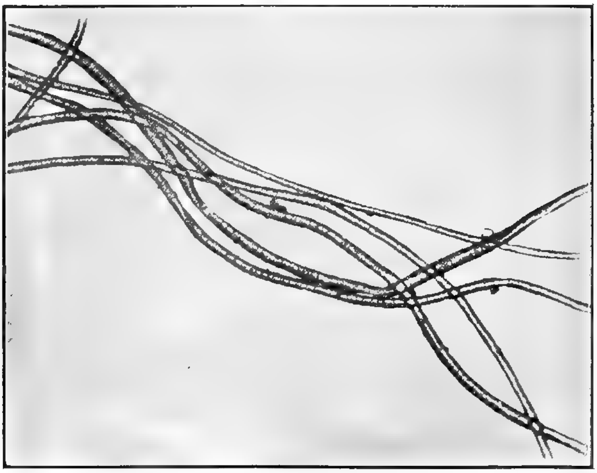

FIG. 214.—MICROPHOTOGRAPH OF WOOL FIBERS.

Ramie.—Ramie Fiber or China Grass is a fine, silky fiber obtained from a nettle plant native of China. It is an excellent fiber, but the great difficulty and expense of separating it from the stalk has, up to the present time, prevented its extensive use.

Wool.—Sheep's wool is by far the most important of the animal fibers. The term wool is applied to the hairy covering of a number of animals, but in the strictest sense it is the hairy covering of the sheep. For practical reasons, the hair of certain goats, as the Cashmere, Mohair and Alpaca, are often classified as wools.

To be suitable for spinning into yarn, a fiber must possess sufficient length, a high degree of flexibility and elasticity, and

what is more important, an outer surface of such a character that one fiber will adhere to another, and not too readily slide along the surface of the others when such yarn is subjected to tension. Furthermore, such a fiber should be capable of being easily cleansed, of readily absorbing dyestuffs, and not too easily affected by atmospheric conditions and chemical reagents. In sheep's wool, we find an almost ideal fiber for the manufacture of yarn and cloth. Wool fiber has a characteristic physical structure which distinguishes it from other fibers. Under the microscope wool always exhibits two and sometimes three structural portions. The outer portion consists of an external horny covering composed of broad horny plates, all projecting in the same

FIG. 215.—RAW WOOL FIBERS, SHOWING GREASE.

direction and much resembling the scales of a serpent. This serrated structure of wool fiber is an extremely important element in the various processes of finishing cloth made of wool. The underlying portion of the fiber, which constitutes the chief portion, and known as the *cortical*, is built of minute spindle-shaped cells of a more or less horny character. It is this portion which contributes to the strength and elasticity of the wool, and which absorbs coloring matters during the dyeing process.

The *medullary* or *central portion* of the wool, although easily seen in certain coarse wools, is usually invisible in fine wools. It is composed of larger and less defined cells than the cortical and is of a marrowy nature. Wool fibers vary greatly in length, not only from different sheep but from different portions of the same sheep. The maximum length of wool fibers is placed as high as twenty inches, but this extreme length is very unusual. As used by manufacturers, the average length is between two and six inches. Wool, as it comes from the sheep's back, is heavily laden with foreign matter which usually is far in excess of the actual fiber. Actual wool fiber is found to possess chemical properties similar to horn and feathers, and to consist chiefly

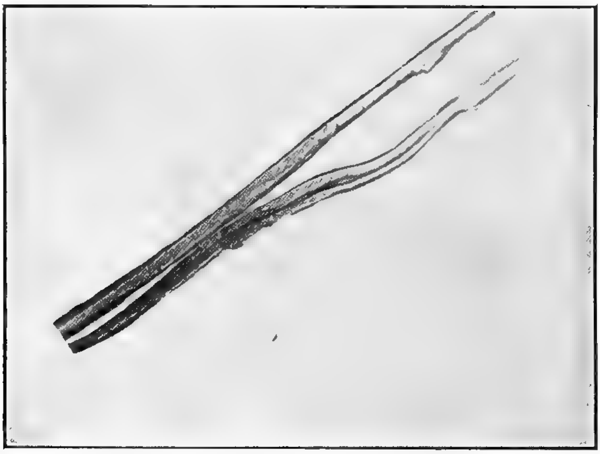

FIG. 216.—RAW SILK FIBER (SERICINE NOT REMOVED).

of an albuminoid substance termed *keratin*. The accompanying substances of wool fiber may be classified under three headings. (1). The *suint* or *wool perspiration,* constituting the portion which is soluble in warm water, and consisting largely of the potassium salts of various organic and inorganic acids. (2). The yolk or *wool fat,* comprising the portion insoluble in water, but soluble in ether, naphtha, and various other organic solvents, and consisting of a mixture of fatty substances known collectively as *wool grease.* (3) The *mechanical impurities,* consisting chiefly of insoluble mineral matter, but also including burrs, straw, and

other substances, all of which are held mechanically to the wool through the adhesive nature of the suint and yolk.

The following figures will show the wide range of variation in the composition of raw wool:

Actual wool fiber	20 to 75%
Combined yolk and suint	10 to 60%
Mechanical impurities	3 to 30%
Moisture	6 to 30%

As a rule, the best grades of wool are accompanied by the highest percentages of combined yolk and suint. The accompanying substances of wool fiber especially concern the wool merchant and manufacturer, since the amount present varies greatly and is an important factor in determining its value. To

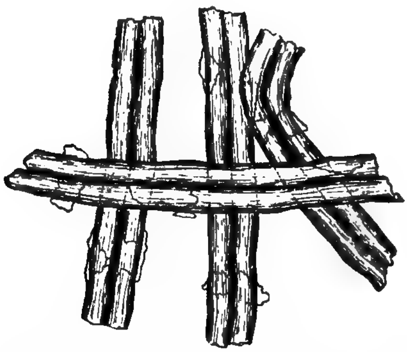

FIG. 217.- A DRAWING OF RAW SILK FIBERS.

the dyer they also possess a special interest, for upon the thoroughness of their removal, the success with which pure, even and fast dyeings may be obtained depends to a large degree.

Silk.—Cultivated or artificially reared silk is the product of the common silk moth (*Bombyx mori*), which has been cultivated and studied for a period of several thousand years. The important sources of cultivated silk are Southern Europe, particularly France and Italy, Turkey, China, India and Japan. The United States has never been a successful cultivator of the silk worm, although the use of silks has increased remarkably during the past few years, and today the United States is one of the largest consumers and a leading silk manufacturing country.

The eggs of the common silk worm are about the size of poppy seeds, and from these the silk worms, or caterpillars, are

hatched. These worms are fed regularly upon the leaves of the mulberry tree for a period of from four to four and one-half weeks, when they stop eating and are ready to spin. When the spinning operation begins, the silk worm builds about itself the cocoon in which it lives during the chrysalis state. While spinning, the silk issues from the spinneret of the silk worm at the rate of from four to six inches of silk per minute, and in from three to five days 1,500 to 4,000 feet of silk have been spun. From a perfect cocoon this entire amount of silk may be reeled as one continuous thread, and, if carefully done, without a single break. Silk fiber differs from vegetable fibers as well as from wool in that it is void of cellular structure.

Raw silk as it comes from the silk worm is a double fiber. This is due to the fact that there are two different systems of glands within the body of the silk worm which produce the silk substance, the two conveying ducts from these uniting just before they reach the spinneret. The silk substance begins to harden and assume the fibrous condition before this point of union is reached, hence the double fiber. When examined under the microscope, silk fiber has the appearance of two cylindrical semi-transparent fibers which are held together by a substance known as *sericine* or *silk gum.* Chemically speaking, silk is composed of two different substances. The *fibroin* or *true silk fiber,* which is insoluble in water, constitutes about two-thirds of the raw silk. The *sericine* or *silk gum* is soluble in water. This latter substance is almost entirely removed during the various processes of manufacturing and finishing silk textile material. Silk fiber is characterized by its lustre, strength, and elasticity. It also possesses remarkable avidity for moisture, frequently carrying from 25 to 30 per cent. of hygroscopic water, without feeling in the least degree moist.

In addition to the cultivated silk, there are at least four well-defined varieties of wild silk which are commercial articles.

Artificial Silk.—The high lustre, as well as other valuable properties of silk fiber, has always made it extremely desirable for many purposes. As the high cost of natural silk prevents its use in most cases where cheapness is a necessary consideration, numerous investigators have turned their attention at different times to the problem of producing an artificial silk, or better, a

silk substitute. *Mercerized cotton,* which we shall discuss later, accomplished the desired result to a certain extent, but as mercerized cotton is actual cotton fiber which has simply been modified by a special treatment, it should never be classified as an artificial silk, although it is, to a limited extent, a silk substitute.

A number of methods have been tried for manufacturing artificial silk, but the only ones that have met with any success are those which produce a very fine cylindrical filament by forcing through a capillary orifice some semi-liquid substance which may be easily solidified after emerging from the orifice. The semi-liquid substances successfully used for this purpose have all been some cellulose preparation, and for this reason the common artificial silks are frequently designated as *lustre celluloses.* The oldest, and for a long time the most successful of these processes, was the one introduced by Chardonnet in 1884. This process is based upon the fact that a solution of tetra-nitro-cellulose solidifies when brought into contact with cold water. A properly prepared solution of this tetra-nitro-cellulose, commonly known as pyroxylin or collodion, is forced, under considerable pressure, through a very fine capillary tube, the end of which is immersed in cold water. Upon issuing from the orifice and coming in contact with the cold water, the pyroxylin solidifies and can be drawn out and reeled in the form of a continuous fiber. In brilliancy, artificial silk frequently surpasses the natural, and for many purposes where durability is not an extremely important consideration and the material is not likely to be subjected to the action of water for any length of time, its use is very satisfactory. It is extensively used in the manufacture of braid, dress trimming, lace and neckwear. For the manufacture of cloth it cannot be used successfully alone, but in conjunction with other fibers, particularly cotton and wool, a certain amount may be used to advantage.

The *secondary raw materials* of the textile manufacturer, namely, bleaching, scouring and coloring agents, will not be especially and individually discussed as have been the primary materials of fibers. They will, however, be briefly discussed in connection with the various stages of the manufacturing processes during which they are regularly used.

(2) *Processes of Converting Raw Materials Into Finished Textile Fabrics.*

All fibers contain varying amounts of impurities, both natural and foreign. These must be removed before the fibers are of such a character as to be used for the production of white goods or to be dyed delicate tints or light shades. Most textile materials, therefore, must be given certain preliminary treatments before they can be properly dyed and finished, and in certain cases, particularly with wool, it is even necessary that these impurities be removed before the fibers can be manufactured into yarn. These preliminary treatments may be given when the fiber is in the loose or unspun state, as is usually the case with wool, when it has been made into yarn, as is the case with silk, or when it has been woven into cloth, as is commonly the case with cotton and linen.

With cotton and linen these preliminary treatments are known as *boiling out* and *bleaching,* with wool as *scouring* or *degreasing,* and with silk as *boiling off* or *degumming.* Silk and wool are occasionally bleached in addition to the processes just mentioned.

Cotton Bleaching.—Cotton material is almost always bleached in the form of cloth or piece goods. It is only when special requirement demands that it is bleached in the form of yarns, and very seldom in the loose or unspun state. In general, the process consists in first boiling the material with lime, soda ash, or caustic soda for a number of hours under pressure, in specially constructed boilers known as kiers. After this treatment, the material is subjected to the action of a cold, dilute solution of *"chloride of lime"* or *bleaching powder,* this being followed by a treatment with a dilute acid solution. The active portion of the bleaching powder is the *calcium hypochlorite* which it contains. By a series of somewhat complicated reactions nascent oxygen is finally liberated which is the most active of all bleaching agents. This process must be carried out with great care, because improper boiling or the use of too strong hypochlorite or acid solutions, or too long duration of the process may result in injury to the fiber. Sodium dioxide or hydrogen dioxide may also be used in cotton bleaching, but high cost prevents their application for this purpose, except in very special cases.

Wool Scouring or Degreasing.—The accompanying impurities of raw wool are so abundant and of such a nature that they must be removed before even the first steps of the manufacturing process can be carried out, otherwise they would soon cause a serious gumming of the machinery, as well as other hindrances to the process. The process of removal is generally known as wool scouring, and consists in working the wool in specially constructed machines, known as wool washers, together

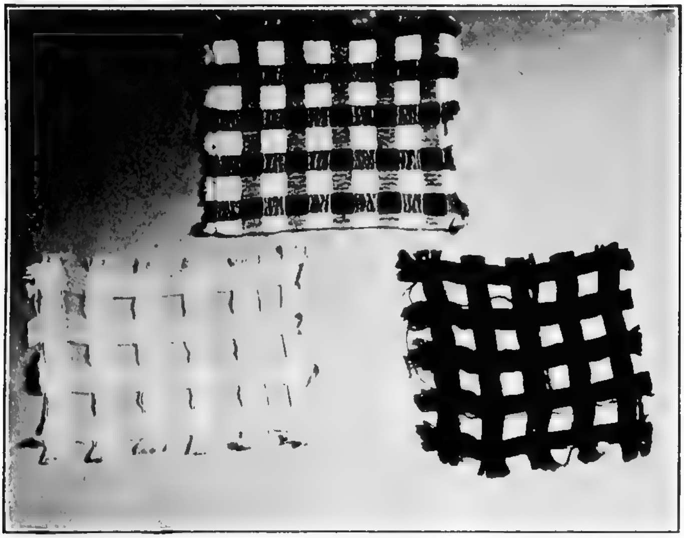

FIG. 218.

In this figure the upper piece of cloth is composed of cotton and woolen yarns, the black representing the wool and the white the cotton. The lower left hand figure represents a piece of the same cloth with the wool removed by boiling in caustic soda solution, and the lower right hand figure a piece of the same cloth, with the cotton removed by the action of sulphuric acid.

with a warm soap solution containing a small quantity of potassium or sodium carbonate. In this country but little attempt is made to recover the grease, either of the raw wool or soap, and enormous quantities are wasted annually. One notable exception to this is the Arlington Mills, which has perfected an extensive plant for extracting the wool grease by naphtha, and it is said that the return from the sale of the wool grease is sufficient to pay the whole cost of degreasing the wool.

Silk Degumming.—As already described, raw silk consists of two structural portions: the *fibroin,* of which the two intimate silk fibers are composed; and the *sericine,* which, owing to its gummy character, holds the two individual fibers together and gives the whole the appearance and feel of a comparatively rough and harsh individual fiber. In order to develop to the highest degree the lustre and smoothness characteristic of silk fiber, as well as render it suitable for subsequent dyeing and finishing, the sericine must be removed previous to manufacture into cloth. This is accomplished by working the raw silk in a bath of olive oil soap solution for several hours at a temperature just below boiling. The resulting liquor, which contains the extracted sericine, is known as *boiled off liquor,* and makes a valuable addition to the bath during subsequent dyeing processes. Silk and wool are most frequently bleached by the action of sulphurous acid, although the peroxides of sodium and hydrogen have met with increasing favor during recent years.

A detailed description of the mechanism of the processes involved in the conversion of textile fibers into cloth, and of the various machines used, is entirely beyond the scope of this chapter, as it is more particularly our object to discuss the actual materials used and the nature of the finished product.*

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*However, the following brief description of the manufacturing process is given for the sake of completeness.

In general, the fiber is first passed through opening and picking machinery, and from thence to the cards. The carding process takes the fibers which have previously existed in tangled bunches, isolates the individual fibers, and then brings about a uniform aggregation of these isolated fibers into a continuous coherent fleece, which, after being drawn through a small conical orifice, is known as *sliver* or *roving.* During the carding process many mechanically adhering impurities are removed, as well as excessively short fibers. In general, the spinning process follows the carding, but in the manufacture of worsted yarns, as well as fine cotton yarns, a combing process intervenes, which has for its object the combing out of the shorter fibers and placing of the longer fibers parallel. Two types of spinning machines are in use, namely, the ring spinning frame and the mule, but in either case the process is one of the drawing out and twisting of the roving. The actual production of cloth takes place in the loom, the yarn running lengthwise of the cloth being called the *warp,* and that which passes across the *filling* and sometimes the *weft* or *woof.* By proper regulation of the manner in which the filling threads pass under and over the warp threads, and by the use of different colored yarn, it is possible to produce innumerable patterns. In the manufacture of silk material a number of individual silk fibers are reeled directly from cocoons and twisted together loosely, and in this form constitute the *tram silk,* which is used for the transverse thread or filling in the weaving of cloth. The fiber from the best cocoon is not only twisted in this way, but the threads thus formed are doubled and twisted again, forming *organzine,* which is stronger and harder and more suitable for the warp than tram. The broken and injured cocoons are picked to pieces, and the resulting fiber carded, combed and spun into yarn. It is known as *spun* or *floss silk. Knit goods* or *hosiery* are made from yarn upon knitting machinery, which mechanically apply, in a very ingenious way, the same principles as are applied by hand with knitting and crochet needles.

In the majority of cases cloth is made from one kind of fiber, but very frequently two different fibers are combined, and sometimes three. The commonest method of combination is by use of a warp of one fiber and filling of another, such cloth being designated as union cloth. Another method is to actually mix the two fibers before carding, thus producing a uniform mixture through both warp and filling.

Dyeing, Printing and Finishing.—Whether a fabric is merchantable or not, its acceptance in competition depends more upon the work of the dyeing, printing and finishing departments than of any others. This is particularly true in the woolen mill, where the dyeing and finishing ordinarily cause the manufacturer more anxiety than the work of all the other departments combined. If the dyer and finisher are competent men they can do much to improve a poorly manufactured fabric.

The early textile colorists depended almost wholly upon certain vegetable and animal products for their coloring agents. Inorganic or mineral substances were sometimes used, but the former held by far the most important place in the art of dyeing, and were classified as the natural dyestuffs. The natural dyestuffs remained the leading factors in textile coloring until 1856, when Perkin discovered that a coloring matter, which he designated as *mauve,* could be made from certain coal-tar derivatives. Three years later *magenta* was discovered. These so-called *coal tar colors* were rapidly followed by others, and they have increased in number and importance to such a degree that the older natural dyestuffs have, with one or two exceptions, now become obsolete.

In general, there are four important classes of coloring matters used in the dyeing of textile materials—substantive or direct colors, mordant colors, reduction vat colors, and those which are actually formed upon the fiber during the process of dyeing.

Direct colors are those which are soluble in water, and which will dye one or more of the common textile fibers directly from such a solution without the necessity of any other additions, although to facilitate matters certain assisting substances are commonly added to the dye bath. The majority of the coal tar coloring matters belong to this group.

Mordant colors are those which have no direct affinity for any of the fibers, and can only be applied in conjunction with some secondary substance, usually an oxide of chromium, aluminum or iron, designated as a mordant, which has been previously fixed upon the fiber. The mordant colors are more difficult to apply and more expensive, but produce much faster dyeings than the direct colors.

Reduction vat colors, of which indigo is an excellent illustration, are insoluble in water, and have no affinity for textile fibers in their ordinary form; but when energetically reduced in an alkaline bath, they pass into solution, and in this form are rapidly absorbed by textile fibers. Upon exposure to air the reduced dyestuff rapidly oxidizes to its original insoluble condition and becomes permanently fixed upon the fiber.

The dyestuffs of the three classes just mentioned are all commercial articles. The fourth class is not extensive, and includes only such dyestuffs as *aniline black* and *para red,* which are actually manufactured during the process of application. The above classification is an extremely broad one, and is only used to indicate the most dissimilar classes. In practice the coal tar coloring matters are divided into at least ten different groups, and from the point of view of chemical composition into more than thirty.

Dyestuffs may be applied to the fiber before it is spun into yarn, to the yarn, or to the finished cloth. In the latter case the process is known as piece dyeing, and is the most desirable method, as it is the cheapest and most convenient. For many purposes, however, it is necessary to resort to one of the former methods.

Textile printing is very extensively carried out, particularly upon bleached cotton cloth, although cloth made wholly of wool is also printed.

Finishing processes are extremely varied, and in general are less complicated with cotton cloth than with cloth composed of all wool or cotton and wool. They are difficult to clearly describe without going into great detail, and cannot be discussed at this time.

There is one process which, although not, strictly speaking, a finishing process, should be mentioned, namely, *mercerization,*

so called after John Mercer, the discoverer of the process. It consists in subjecting cotton material—for it is only applicable to cotton—to the action of a cold concentrated caustic soda solution. The chief value of the process lies in the fact that a decided lustre is imparted to the cotton yarn or cotton cloth, when they are mercerized under tension. Mercerization also imparts to cotton an increased affinity for many dyestuffs.

(3) *The Consumers' Interests and Rights.*

During recent years the government, both national and state, has been extremely active in formulating and enforcing laws for the protection of the general public against misrepresentation and adulteration of foodstuffs. With this in mind the opinion has been expressed frequently that the government should also exercise a similar control over the sale of textile material. While this would undoubtedly be a great advantage to the consumer, and certainly it is his right to know just what he is buying, it is by no means of as great importance as the supervision of foodstuffs.

A critical attitude is frequently taken concerning the practice of mixing cotton and shoddy with wool in the manufacture of cloth, particularly for clothing. In the long run, however, this practice is really in the direct interest of the consumer rather than otherwise. Let us consider the facts.

In the first place, what is shoddy? Shoddy is wool fiber which has been recovered from old wool rags and waste, by picking the rags to pieces by machinery and separating the wool fibers into a more or less isolated condition. When cotton fiber is present, this is removed by the *carbonization process,* which consists in saturating the material with a solution of some mineral acid, or acid liberating substance, and then drying at an elevated temperature. During this treatment all cotton, as well as other vegetable matter, is disintegrated to a dust-like substance, without any pronounced injury to the wool. The result is a loose mixture of pure wool fibers of lengths varying from one-third to as much as two inches in length. When shoddy is made from worsted rags, the individual fibers of the shoddy will be of the greatest length, and in many cases a high grade shoddy is of better value in the manufacture of cloth than a low grade wool. The prices of wool which have prevailed during the past few years have

been extremely high, consequently all wool fabrics made of the best grades of wool are naturally of a correspondingly high price. In order to manufacture cloth suitable for men's wear, which one of moderate means could afford, the manufacturer introduces a certain percentage of cotton or shoddy along with the wool and produces a fabric which can be sold for two-thirds and in some cases one-half the price of a corresponding fabric made entirely of high-grade wool. The skilful dyer and finisher can make the former look almost as good as the latter, although its wearing qualities may not be quite as great. In general, the consumer is thus benefited from the point of view of economy. Many excellent fabrics used in the manufacture of women's wear have a cotton warp and wool filling, and are sold at comparatively low cost, while the price of a similar all-wool fabric would be prohibitive for many.

Upon the whole, textile manufacturers are honest and their prices are in direct proportion to their cost of manufacture. There are, however, several other hands through which cloth must pass before reaching the consumer, namely, the jobber who sells to the clothing manufacturer, the wholesale clothing manufacturer and the retail dealer, and thus there is plenty of opportunity for misrepresentation along the line.

In the purchase of textile material the main fact to be borne in mind by the consumer is that the presence of cotton, or even shoddy, in a piece of goods is perfectly legitimate, provided that the price paid is sufficiently low for such material. The real danger lies in the fact that, through misrepresentation, he may pay for a low grade fabric or garment the price which should purchase one of all wool. Such misrepresentation is often made in regard to blankets, which are frequently sold as all wool when they contain twenty-five per cent. or more of cotton. It may be of value to the consumer to know that if a piece of cloth, boiled for ten minutes in a 10 per cent. solution of caustic soda, does not entirely disintegrate and disappear, it is not all wool.

There are practices, however, which may be looked upon as actual fraud, namely, the heavy weighting and filling of both cotton and silk material. Colored silk, particularly black silk, cloth may be weighted by the addition of certain metallic organic combinations, particularly of iron and tin with tannin, to the ex-

tent of more than three hundred per cent. In other words, one pound of actual silk is converted into four pounds of black silk cloth. Such cloth leaves a very heavy ash upon ignition, and thus a simple method presents itself for detecting such adulterants. In justice to the manufacturer of silk material, let it be said that a small amount of such weighting is not injurious and may facilitate the dyeing process, but excessive weighting is always injurious, renders the silk harsh and brittle, and diminishes the durability of the goods. This is very frequently illustrated with black and white silk checks, and many a woman has been dismayed to find the black portion of such cloth so tendered go to pieces, when touched, whereas the white portion was as strong as when new. Inferior grades of white cotton cloth are frequently heavily weighted and filled with barium sulphate, starch and other finishing materials to render them salable, which, after the first washing, prove a great disappointment to the purchaser.

Another matter of vital importance to the consumer is the question of permanence or fastness of colored textile material. The qualities demanded of any particular coloring matter depend upon the conditions to which its uses will necessarily subject it. Therefore, the requirements vary greatly. Taking any one of the numerous dyestuffs at random we may find that it is particularly well suited for one branch of textile work and wholly unfit for another. For example, textile material for ladies' evening dresses, which at the most are worn but a few times and then subjected only to artificial light and the mildest of color-destroying agencies, need not be very fast. On the other hand, cloth which is to be manufactured into suits for sailors, soldiers and policemen must be dyed with such coloring matters as will give resistance to the prolonged action of sun, rain, and, in the case of sailors, salt water. To be of superior quality, curtains, draperies, furniture coverings and rugs should possess fastness to light and rubbing, but their fastness to water is of much less importance, and their resistance to alkalies and acids need scarcely be considered. On the other hand, it is taken for granted that colored underwear, including stockings, need not be especially fast to light, but it is extremely important that the color should not crock or rub, and should be able to withstand the action of perspiration, a certain amount of heat, and frequent washing in warm

alkaline soap baths. Many other examples could be mentioned, but we will simply enumerate the more important color-destroying agencies toward which the fastness of dyestuffs is usually tested. They are, fastness to light, weather, washing, ironing, rubbing, perspiration, acids, alkalies, chlorine, sulphur dioxide, fulling and steaming. Of these, the first six only are of interest to the purchaser, the others being simply of importance to the manufacturer. In general, it may be said that if dyed material will withstand the continuous action of sunlight for five weeks it possesses

FIG. 219.—THE LOWELL TEXTILE SCHOOL, LOWELL, MASS.

excellent fastness to light. Certain coloring matters will give evidence of fading upon one day's exposure, and in such cases they are said to be extremely fugitive. A dyestuff that will withstand the action of sunlight for two weeks before fading possesses sufficient fastness in this respect for ordinary purposes.

The antagonistic views advanced by many people against the coal tar colors appear without foundation to those possessing a scientific knowledge of coloring matters and the conditions which govern their use in any particular case. For instance, dealers in

Oriental rugs, and the enthusiastic collectors of the same, who obtain their information chiefly from the former, are particularly noted for their bitter attacks upon the coal tar colors, which they usually designate as the *aniline dyes*. If these antagonists used the term aniline dyestuffs in its true sense, there might be more truth to their assertions, because among the true aniline colors we have some of the brightest and at the same time most fugitive dyes known, but they use this term as being synonymous with coal tar colors. This use of the name aniline dyes, to designate the coal tar coloring matters in general, is erroneous, for a large proportion, in fact, the fastest of the artificial coloring matters, is in no way related to aniline. In making the above statement there is no intention to detract from the value of the vegetable dyestuffs for the production of certain effects, nor to belittle in any way the ability of the Oriental colorists, many of whom possess secrets which might prove of value to the modern dyer, but to emphasize the following opinion, namely, that an expert textile colorist could, in practically every case, by the use of the proper coal tar coloring matters, match any particular color which had been produced upon textile material with natural dyestuffs, and produce dyeings which would be as permanent if not more permanent than those produced by the latter.

Fifteen or twenty years ago the United States was much concerned in regard to the rapid development of the textile industry abroad, particularly in Great Britain and Germany, and the supremacy which these countries were rapidly gaining. Investigation led to the belief that the numerous textile schools abroad were important factors in this development. American manufacturers were wise enough to realize the value of such institutions, and during recent years several have been established in this country. The beneficial influence of these schools is already noticeable, and as time goes on the textile industry in America will rest entirely in the hands of technically trained men. With this the case we need have no fear for its future.

CHAPTER XXV

Combustibles and Explosives and Their Relation to the Fire Risk in Cities.

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The question of fire control in great cities covers, in its broadest sense, the whole field of combustion and its consequences, direct or indirect. The phenomena of combustion are purely chemical, and can only be correctly understood by a chemist. Oxidation in all its phases, from spontaneous ignition of moist or oily fibres to the explosion of dynamite, are within his sphere, and his knowledge of the conditions governing its phenomena must be the basis of all regulations for the handling and control of the materials of this large class. This fact was recognized in the establishment in 1902 of the Municipal Explosives Commission of New York City, and in the requirement that one member of the Commission should be a chemist. The regulations made by this Commission are practically the laws to which all who make, sell or use combustibles and explosive materials are subject. As the ordinance establishing the Commission also gives it wide discretion as to the materials which shall come under its authority, there is provision for control of any other dangerous materials which may come into use through the development of trade or invention.

Nature of the Materials.—Combustion in air is the form of combustion most familiar to us, and the active agent in this process is oxygen. The atmosphere is a great sheet of gas, one-fourth oxygen by weight and three-fourths nitrogen. The lesser ingredients, carbon dioxide, and the rare gases, argon, xenon, neon and krypton, are of no importance in this connection, and are included in the figures for nitrogen. The air presses about one ton upon each square foot of the earth's surface, about the weight of a pillar of iron five feet high and one foot square. If

it were concentrated in a uniform layer having the density of the air now at the earth's surface, it would be about five miles thick. If this mass were passed at the rate of a mile a minute through a square tube 710 feet in cross section, it would take about 100,000 years for the entire mass to pass through. We use oxygen in many ways—for breathing, for combustion in furnaces, and in many processes of manufacture. We are beginning to use the nitrogen of the air in making nitrates and other commercial materials, but all of these uses tend in a relatively short time to return these ingredients again to the air. None of these uses, even if developed a hundredfold, could alter the constitution of the atmosphere by as much as one per cent. of either of its ingredients in a century. The atmosphere is a mine of raw material costing nothing and inexhaustible in supply. Conservation of natural resources, therefore, is not as yet a burning question, in any sense, so far as the atmosphere is concerned.

Most of our processes of oxidation, including combustion, depend upon the free oxygen of the air. Its effective use in oxidation for any given purpose is a question of regulation only. Acting slowly and at ordinary temperatures, it dries our paints and contributes to the slow decay of organic material. Warm, its action may be accelerated from stage to stage, always under control, from the blacksmith's forge to the blast-furnace 120 feet in hight and turning out 600 tons of molten iron in a day. Once beyond our control, it becomes a raging fury which may devour a whole city in a day.

For manufacturing purposes, however, it is necessary in many cases to have oxygen in a form in which it can be used rapidly yet without production of great heat, or for progressive chemical action under conditions in which the use of free oxygen is not possible. There are many chemical compounds, which we shall designate hereafter as *oxidizers,* which contain oxygen condensed and locked up in forms more available than the oxygen of the air. Such oxidizers are rare in nature; ozone, hydrogen peroxide and nitrates, especially those of potassium and sodium, and manganese dioxide, practically fill the list. All of these may yield oxygen, under conditions, with artificial heat or without. Natural nitrates result from processes of decay of organic matter in the

soil, especially in warm and dry climates. Potassium nitrate, or saltpeter, is brought principally from India as a natural product obtained from leaching the soil. Artificially, it is now made in great quantities by the decomposition of natural sodium nitrate with potassium chloride, also a natural product obtained from the mines of Stassfurt, Germany. The artificial product is said to contain small quantities of potassium perchlorate, which is now of some interest in the manufacture of explosives. Sodium nitrate comes into commerce from only one source, a superficial deposit in a desert region of northern Chili. It is almost the only commercial source of nitric acid and metallic nitrates. Nitric acid, however, is now made commercially in Norway by direct combination of oxygen and nitrogen of the air under the influence of the electric arc. The manufacture is a growing one, and will soon be an important contribution to the world's supply of nitric acid and nitrates.

There is a large class of oxidizers of artificial origin which adds greatly to the resources of chemical manufacture. The most important of these are the chlorates, especially the potassium and sodium salts. Potassium chlorate yields oxygen in abundance at a moderate heat and has much application in manufacturing, notably in dyeing and in making of matches and fireworks. Apart from these, it is in common use as an application for inflamed mucous surfaces, and on this account alone it is freely sold in the drug stores. Many accidents and some criminal explosions have resulted from this ready supply of a dangerous material. It would be well if its sale at retail could be abolished. It is unsafe to store and handle, because in contact with organic matter it produces explosions under slight heat or friction. Sodium chlorate has the same general properties, but is not in common use except on a large scale.

Permanganates, principally the potassium salt, figure largely in manufactures, and the latter, being used as a disinfectant, is freely sold at retail, and, like the chlorate, though in a lesser degree, it is dangerous in contact with organic substances. Permanganates should be handled and stored under the same precautions as chlorates. Chromic acid has considerable commercial importance as a strong and active oxidizer. It is especially dangerous, and can be kept only in glass. Peroxides of hydrogen,

potassium, sodium, calcium and barium, and in a lesser degree those of lead, manganese and zinc, are commercial articles; all yield oxygen when heated, and all form explosive mixtures with finely divided organic matter. Sodium and potassium peroxides evolve oxygen and heat in contact with water. All high oxidizers are especially dangerous in case of fire, because they liberate oxygen at a stage when the fires have attained some headway and their decomposition intensifies enormously the rate of the combustion. The especial field for the use of high oxidizers is in the manufacture of explosives, which are commonly mixtures or compounds containing high oxidizers intimately associated with combustible matter. Practically all explosives owe their force to decomposition products of nitric acid or its derivatives. Chlorates are used in high explosives to a slight extent, and their use may increase, but they represent at present a very insignificant portion of the high explosives used. As to other oxidizers, their cost would be an objection to their use in high explosives, and most of them are entirely unsuited for other reasons.

The term *"combustibles,"* as commonly used, includes all substances that unite with oxygen with the production of heat and light. The rate at which combustion or oxidation goes on depends upon the nature of the substance itself. There is a critical point in starting combustion, and heat is commonly necessary from some external source, in order to bring the material to a temperature at which the heat set free by chemical action will be in equilibrium with that lost by radiation. This is the *kindling temperature,* and above this temperature combustion maintains itself. The kindling temperature has a wide range among combustibles, and much depends also upon the physical state of the substance. Combustion in the air is a surface phenomenon, and the greater the surface exposed to the air above kindling temperature, the more rapid will be the combustion. For a given surface and a given material, the rate may be increased by increasing the supply of air to each unit of surface in a given time. This is what is commonly called "draught" or air supply. In a wider sense, the rate or intensity of combustion depends simply upon the number of atoms of oxygen that can be taken into combination within a given space and in a given time. And this rate is measured by the number of heat units evolved by

the burning mass in a unit of time. A heat unit, however otherwise defined, is, in general terms, the heating effect which can raise one unit weight of water through one degree of temperature.

Combustibles may be divided for convenience into two classes, combustibles proper and inflammables. In the first class we put most solid combustibles, such as wood, charcoal and coke, pitch, asphalt, starch, sugar, dried herbs, dried roots, etc., also heavy oils of high boiling-point (above 300° F.). Such materials do not kindle readily and are not, commonly, the materials in which fires originate. *Inflammables* include combustibles in a fine state of division, or offering large surface, as shavings, paper, straw, hay, sawdust, excelsior and other fibres, also phosphorus, sulphur and some sulphides. In the same class are put all combustible gases, vapors of liquids which boil at temperatures below 300° F., and the liquids from which they come. The two classes merge into each other by reason of subdivision, so that even such combustibles as coal and wood become dangerous inflammables in the form of fine dust, and when mixed with air may even produce explosions. Flame is burning gas, and the burning of gas occurs only when it is in contact with air or oxygen at the igniting temperature. In a vessel entirely filled with illuminating gas, a match might be struck without the slightest danger, while if a lighted match were applied at the mouth of a vessel where gas and air came together, the gas would burn; and if air and gas had been previously mixed within the vessel, the mixture on igniting by the flame of the match would explode, because it would burn simultaneously in all parts of the mixture.

Volatile oils, especially the different liquids distilled from crude petroleum, are among the most dangerous inflammables known. The three liquids, gasoline, benzine and kerosene, the latter especially, are more widely used in cities because of their domestic application than any other combustible liquids. These three liquids are distinguished in commerce by their specific gravity, and the specific gravities run parallel with difference of boiling point, upon which their safety for general use depends. Specific gravity is commonly expressed in terms of the Baumé hydrometer.* For liquids lighter than water the grade rises as

*It is to be hoped that the use of the Baumé and Twaddle hydrometer scales may soon be discontinued entirely and that the sensible and scientific specific gravity terms be adopted instead, as has been done by many of the most prominent manufacturers.—C. B.

the specific gravity of the liquid decreases, so that the more volatile liquid has the higher Baumé figure. Gasoline runs from 76° to 92° Baumé; benzine (including naphtha) from 62° to 76°, and kerosene below 60°. These liquids are further distinguished, for purposes of safety, as well as for other reasons, by their flashing-point, by which is meant the temperature at which the liquid gives off sufficient vapor to form at its surface an explosive mixture with the air. Kerosene is required by law in New York City to have a flashing-point above 100° F. Benzine and gasoline are considerably lower and flash generally at ordinary temperatures. For use in combustion engines, the lighter liquid, gasoline, is most commonly used, and the question of specific gravity is an important one in determining its use for the higher class of motors. There are certain very light distillates from crude petroleum of higher grade Baumé than gasoline, and therefore of lower flashing-point, but they are too dangerous for common use and have no common application. Lighter distillates of coal tar are also of commercial importance, benzol especially; its higher homologues, toluol, etc., are less volatile and have less common application. Alcohol, ether (so-called sulphuric ether, used as an anæsthetic), wood spirit (methyl alcohol), acetic ether and other ethers of its class, carbon disulphide and acetone, are the principal other commercial volatile liquids that are used in sufficient abundance to be considered as sources of danger. Oil of turpentine has a flashing-point so near 100° F. that it may be roughly classed with kerosene, although it is slightly more volatile than kerosene at its lowest permissible point.

Most solids and liquids which are combustible ignite only after they have been so heated as to evolve vapor and permit the raising of this vapor to the kindling temperature. Phosphorus rises to this temperature through the heat evolved by its own oxidation, beginning at ordinary temperatures. It can ignite spontaneously, therefore, in the air. Sulphur is very inflammable, because, while it has a high boiling-point, it has a low melting-point and a high vapor tension, so that enough vapor is sent into the air, even at temperatures little above the melting-point of sulphur, to produce an explosive mixture with the air. The flame of burning sulphur is persistent and hard to extinguish.

The igniting temperature of a gas or vapor is that of a flame or an electric spark, both representing temperatures relatively high. Flame is incandescent gas, and vapors of volatile substances ignite only, as a rule, when they have been brought to the temperature of burning gas. An electric spark represents a small portion of air brought to incandescence by a current of electricity, and the heated portion of air represented by the spark must have sufficient mass to communicate its own temperature to a certain mass of the combustible gas or vapor. A very weak spark will fail to ignite a given gas or vapor which may be ignited by a stronger spark. Solid bodies at a glowing heat ignite gases or vapors in some cases, but it is not sufficient, except in rare cases, that the heat shall be merely a visible red. Many vapors refuse to ignite by contact with red-hot charcoal or metal, although they ignite by contact with flame. The question seems to be one of temperature merely, and at a white heat incandescent solids have practically the same igniting power as flame. There are gases and vapors, however, which ignite at temperatures far below visible redness. One of the hydrogen phosphides ignites spontaneously in the air, that is, its kindling point corresponds to common temperatures. Phosphorus does the same, and vapor of carbon disulphide is ignited by a heated rod long before it has attained visible redness. Vapors of ether and the light petroleum distillates, such as benzine and gasoline, ignite only above visible redness, and it is still a question to what extent these materials in admixture with air can be ignited by a spark. It is unsafe, however, to expose them to the heat of a glowing solid, because, ordinarily, such temperatures are less under control and may easily rise during the exposure to the kindling point of the substance. A heated wire kept hot by an electric current affords a more ready control, and accurate results might be obtained through experiments in this line. It is possible, also, that different mixtures of air with a given gas would differ considerably in their kindling point.

Explosion is, in its essence, a form of rapid combustion, and no sharp line can be drawn between the two. Both owe their origin, as they commonly occur, to an effect of heat or to the mechanical force of friction or pressure which is converted into heat. Concussion, which is a common cause of ex-

plosion in unstable substances, results in the production of heat on a sudden arrest of motion upon hard surfaces. Both phenomena may result in chemical action with the production of heat and both yield products of combustion which are mainly oxidized substances. The preparation of *explosives* involves the study of the ratio of oxidizers to combustibles in their composition, because the pressure of an explosion depends purely upon the expansion of the gaseous products of the explosion. The nature of this pressure and the quickness of its application, both of which depend upon chemical action, are yet so modified by conditions depending upon the nature of the substance and the initial source of the explosion, that the phenomena of explosions are best studied apart from the simple question of combustion. Explosive substances may be classed as explosive mixtures and explosive compounds. They are sometimes classed as low and high explosives. Gunpowder is the representative of the first class, explosive mixtures, and practically all explosive mixtures represent modifications of the formula of gunpowder. Some of them contain quantities of explosive compounds so small as to reduce them almost to mixtures of the gunpowder class, but explosive compounds, of which guncotton and nitroglycerine are typical examples, are used generally, whether alone or in admixture, for explosive effects of a higher order than those for which gunpowder is used.

Gunpowder, or black powder, is the earliest explosive of which we have any record. It appeared in Europe in the 14th century, but was probably known to the Chinese at a much earlier date, and there are suggestions of the use of explosive substances even in Europe long before this. It is essentially a mixture of an oxidizer, sodium or potassium nitrate, and two combustibles, sulphur and charcoal, the former by its ready ignition serving to start the combustion, and the latter to continue it and to supply the greater proportion of the heat. A mixure of 75 parts by weight of potassium nitrate, 15 of charcoal and 10 of sulphur, originally a mixture made empirically and with no conception of chemical theory, represents fairly the theoretical proportions for complete oxidation of the combustibles by the oxygen of the nitrates. The mixture carries its own oxygen, and is independent of the air in burning. It will burn in a closed space, and the rate of its burning is limited principally by the rate at which heat

can penetrate the mass. As ordinarily used in grains, the rate of burning is proportional to the fineness of grain, that is, to the surface exposed. The above proportions represent the composition of high-grade powders for ammunition. For blasting purposes, the cheaper sodium nitrate is used and the mixture can have somewhat higher proportions of combustibles because of the greater proportion of oxygen carried by sodium nitrate. The latter, however, absorbs moisture from the air, and such powders deteriorate on exposure. The explosion of black powder results in the production of the gases carbon dioxide, carbon monoxide and nitrogen, along with solid particles of such alkaline salts as sulphates, carbonates and sulphides, which form a white cloud, characteristic of black powder. The quality of the powder depends upon the purity of its ingredients, their fineness and the perfection of their mixture. In theory, every particle of the combustible should be in contact with a particle of the oxidizer, but in practice this is never attained. For special purposes, powders of different composition and different degrees of fineness are used. Blasting powder varies from grains an eighth or less to one-half of an inch in size, and black powder for large guns (cannon powder), which is now largely displaced by high explosives, has been made as large as two and a half to three inches in average dimensions. Meal powder, a finely divided powder, varying somewhat from the proportions above given in its composition, is especially used in fuses and fireworks.

The subject of *fireworks* (pyrotechnics) is a wide one, but the materials used depend upon the principles already given. They are explosive mixtures made to burn more or less rapidly, containing as oxidizers principally nitrates, although chlorates are largely used. The color effects are obtained from the salts of metals, generally nitrates of barium, strontium, copper, etc., and a large variety of chemical substances is used for special effects. Gray antimony sulphide is a common ingredient both as a combustible and for affecting the quality of the light; recently, also, powdered metals, such as aluminum and magnesium, have been introduced, because of the brilliant light effect obtained from them. Finely divided iron (iron filings) has long been used for its sparking effect.

The class of *high explosives* is characterized by containing

an ingredient which is a chemical compound formed from some organic compound through replacement of hydrogen in the molecule by the group NO_2. The effect of this substitution is to render the molecule very unstable, and the effect of its decomposition is the oxidation of the combustible elements in the compound by the oxygen of the NO_2 group. Compounds of this class are generally called nitro-compounds, but a distinction is to be made between those like nitroglycerine, in which the structure involves the attachment of NO_2 to carbon through the intervention of an oxygen atom, and those like nitrobenzol, in which the replacing group, NO_2, is attached directly to a carbon atom.

Nitrocellulose or guncotton is simply cotton with a portion of its hydrogen replaced in part by NO_2. The term "guncotton" is applied properly only to the nitrated products containing the higher proportions of NO_2, and the term "pyroxylin" or "soluble cotton" to the lower nitrated products; the former are highly explosive, sensitive to shock and insoluble in most liquids. Those of the pyroxylin class dissolve readily in a mixture of alcohol and ether, in acetic ether, and in acetone. They burn readily and can be made to explode, under conditions, but they are not commonly classed as explosives.

Nitrocellulose is made by treating ordinary cotton, previously cleaned, with a mixture of strong nitric and sulphuric acids. The quality of the product depends upon the strength of the acids used, the temperature and the time of exposure to their action. The purpose of sulphuric acid in the mixture is merely to preserve the strength of the nitric acid by absorbing the water produced in the reaction. The product is afterwards washed thoroughly, pulped in a paper-making machine and washed in a succession of waters through long periods, to remove any remaining traces of acid. The quality and permanence of the product depend absolutely upon removing every trace of free acid. The last operation is to add to the purified nitrocellulose a small proportion of a substance called a stabilizer, which is either an alkaline substance like sodium or magnesium carbonate or a material which can absorb or combine with any trace of acid which may remain in the product or which may be yielded by its decomposition. The tendency to decomposition is always present in commercial nitrocellulose. Cellulose has probably a very

complex molecule, but is represented in its simplest proportions by the formula $C_6H_{10}O_5$. Its structure is not fully understood, but it is believed to contain three hydroxyl groups (OH), and it is the hydrogen of these groups which is replaced by NO_2, making the nitro-product analogous to an ester or to a metallic nitrate. The formula is commonly doubled or quadrupled to permit the formulation of minute degrees of nitration. The pyroxylines are classed as di- or tetra-nitrocellulose, and the guncottons as tri-, penta- and hexa-products. The terms octo-, deca- and undeca- or dodeca-products refer to an assumed quadruple formula of cellulose. The proportion of three replaceable hydrogen atoms in the simplest formula, as a maximum, is attained, of course, throughout. Guncotton and all of the cellulose nitrates contain insufficient oxygen for their own combustion, and carbon monoxide (CO) is always found in the products of explosion unless an additional oxidizer is added.

The explosive force of guncotton, or the degree of nitration in any form of nitrocellulose, is determined (by a nitrometer), approximately, by the proportion of nitrogen which it contains. In theory, tri-nitrocellulose should yield 14.24 per cent. of its weight of nitrogen. In practice, the results obtained are 13 to 13.4 per cent. The difference is due to impurities in the original cotton, to different degrees of nitration depending upon difference in quality of different fibres (ripeness, etc.), and to the conditions of the operation. This nitrometer test is applicable to the whole series of high explosives made by the aid of nitric acid. Another test, which is of the same wide application, and which is especially intended to determine the rate of deterioration of high explosives of the nitro class, is the so-called "heat test," which depends upon the time required, at given temperatures, for a sample of the explosive to discolor iodized starch paper confined with it in a closed space. By the aid of this test, a general idea can be obtained of the durability of the powder under given conditions of temperature and for a given time. The standards required for satisfactory heat tests vary somewhat, but in general a satisfactory powder must endure a heat of 60° to 80° C. for a period of 10 to 15 minutes, without setting free sufficient nitrous gases to color the test paper to a standard tint.

Nitrocellulose powders at best are not entirely satisfactory. A perfectly good guncotton, if kept continuously in air at a low temperature, would change very slowly, but its rate of change and its deterioration inevitably increase with temperature. Under water it may be kept unchanged for many years. The effect of change is to decrease the safety of the powder for handling and to render it liable to spontaneous explosion or decomposition, or at least to reduce its explosive force.

An extremely interesting product of nitrocellulose is the commercial substance *"celluloid,"* a plastic mass made by kneading together camphor and pyroxylin with the aid of heat and in presence of solvents, generally alcohol-ether mixtures. The material, when dry and seasoned, resembles horn or ivory or hard rubber. It can be worked while warm into any desired shape. The seasoning process involves exposure of the mass in sheets to the action of the air, in warm rooms at varying temperatures up to about 100° F. for long periods. During the seasoning process the solvent is lost by evaporation, but the material is also made less stable by prolonged action of heat. Celluloid is not strictly explosive, though it can, under conditions, produce explosive effects because of the gases set free in its decomposition. The so-called celluloid films used in moving picture machines, are not, technically, celluloid. They are preparations of nitro-cotton.

The nitration of starch to form nitro-starch has assumed some prominence of late, being used as an ingredient of dynamite. It is not hardened by cold and is said to contain as high as 16 per cent. of nitrogen with a corresponding increase in explosive power.

A very important application of nitro-cotton is its use in high explosives, the so-called *smokeless powders.* The white fumes given by burning gunpowder have long been a source of objection for military uses. These fumes not only reveal firing at a distance, but obscure the enemy when near at hand. Powders containing nitrocellulose as an oxidizer yield no fume that is visible because the material itself contains no non-volatile matter except the ash of the cotton, which is never more than two-tenths of one per cent. in the raw cotton, and even this is largely removed by acid in the process of nitration.

Smokeless powders are of two classes, those containing nitroglycerine in addition to gunpowder and those containing guncotton only. The latter class is used exclusively at present for ordnance purposes in the United States. A Government factory at Dover, N. J., is making 1,000 lbs. of such powder each day; there is also a similar factory at Indian Head and several private factories are in operation. The powder is made by dissolving a mixture of guncotton and pyroxylin in appropriate solvents. Alcohol-ether mixture is generally used, although acetone has a wider solvent power and dissolves more of the higher nitro-product than other liquids. The mass, brought to the condition of a paste or jelly by the solvent, is perfectly plastic and the fibrous structure of the cotton has disappeared. It is kneaded to make it homogeneous and uniform, and other ingredients may be incorporated at the same time. The mass, when brought to a proper consistency by evaporation of a portion of the solvent, is shaped into sheets or cords or tubes by appropriate machinery. It is then dried and seasoned by processes analogous to that used for celluloid, but the regulation of temperature must be much more carefully managed, as the product is more sensitive to the action of heat. Smokeless powders are kept under observation during storage, the temperature of the magazines is carefully regulated, and the frequent application of the heat test permits the detection of any changes that may occur.

Nitroglycerine was discovered by Sobrero in 1847 as a product of the action of nitric acid upon glycerine. Glycerine is a derivative of fats and fixed oils, being united in them with a fatty acid. Stearine, a solid fat found in tallow, is glycerine tristearate, that is, it is the ester of glycerol, a triacid alcohol, $C_3H_5(OH)_3$. Nitroglycerine is made by subjecting glycerine to a mixture of the strongest nitric and sulphuric acids, one of nitric to two of sulphuric; the temperature, which tends to rise during the operation and endanger the product, being kept below 78° F. Recent improvements involve the use of sulphuric acid of great strength, made by the addition to ordinary sulphuric acid of 66° Baumé of Nordhausen acid, which contains 89 per cent. of SO_3 instead of 80 per cent., as does the 66° acid. Sulphuric anhydride (SO_3) is also added to the mixture to further increase its strength and to revivify waste acid. The result of this

reinforcement of the oil of vitriol is to prolong the operation, by maintaining the strength of the nitric acid, and to permit the use of larger quantities of glycerine and nitric acid in a given vessel, and therefore to produce a greater yield. In theory, nitroglycerine should yield 246 parts to each 100 of glycerine. The best results in practice are from 220 to 230 parts by weight, while ordinary usage runs from 200 to 210. The product is trinitroglycerine, or actually glycerol trinitrate. Mono- and dinitroglycerine are known, but have no commercial use. The last has a lower freezing-point than trinitroglycerine and has been proposed as an addition, to prevent freezing of dynamite.

The loss is due to impurities in the glycerine, although commercial glycerine is now a very pure product and the loss from this source is slight. It may also be due to imperfect nitration of the glycerine through loss of strength in the acid, and to abnormal increase of temperature by which decomposition products are formed. Nitroglycerine solidifies at 47° F. There is a range of several degrees, however, for these figures, due either to differences in the nature of the compound or to a peculiarity, well-known but unexplained, of difference between the point at which a liquid freezes and the point of temperature at which it subsequently melts. In the solid state it is sensitive to concussion or friction and is very dangerous to handle, and when thawed, it must be heated very slowly, so that no portion of it may attain at any time a temperature much above its fusing point.

Nitroglycerine is a dense liquid of 1.6 specific gravity, having somewhat the color and consistency of honey, a consistency varying with the temperature; the color is due, probably, to impurities. It explodes strongly on percussion and is more sensitive in this respect as its temperature increases. It is very unstable at temperatures above 180° C., but if slowly heated may reach a temperature much higher before exploding. It should be entirely free from acid as tested by litmus, and the processes of washing subsequent to manufacture have this end, especially, in view. It decomposes more readily and is more sensitive to heat or shock when impure. When exploded, it exerts a pressure which has been estimated to be as high as 25,000 lbs. to the square inch, assuming that it explodes without change of volume. The permanence of well purified nitroglycerine is strikingly

illustrated in the statement made by von Schwartz, that a portion of nitroglycerine made by the inventor Sobrero, in 1847, is still preserved in Nobel's laboratory. It is tested every year for signs of decomposition and seems, up to the present time, not to have undergone any change.

The impossibility of using nitroglycerine alone because of its instability led at an early date to its incorporation with an inert material, infusorial earth, which acts as an absorbent for the liquid, giving it a semi-fluid consistency, and also renders it much less sensitive to shock. The first *dynamite* made by Nobel in 1867 contained 75 per cent. of nitroglycerine. Dynamite of this strength is rarely used, however, if at all, at present. The introduction of dry materials that were combustible and along with them of oxidizers, also dry substances, served the same purpose and added to the strength of the dynamite by increasing the heat of its decomposition. At present, the most common proportion of nitroglycerine is 40 per cent., and a typical dynamite contains 40 per cent. nitroglycerine, 15 per cent. wood-pulp, 44 per cent. sodium nitrate, and 1 per cent. calcium carbonate. The variety of mixtures is very great. Many different absorbents of the combustible class are added, and nitroglycerine itself is replaced in part by other nitrated products. Most important of the latter is the mixture of nitroglycerine and pyroxylin or soluble cotton, which is known as nitroglycerine jelly or blasting gelatine. Soluble cotton dissolves in nitroglycerine at moderate temperature and the solution stiffens on cooling to a colloid substance resembling gelatine. In this material, nitroglycerine is bound up and does not leak from the mass. Gelatine dynamite is the same mixture with the addition of an oxidizer, generally potassium nitrate, and a combustible, such as wood-pulp, which also acts as an absorbent. Ammonium nitrate is coming into use to replace sodium nitrate, wholly or in part, in dynamite. It has the advantage of being a more active oxidizer, and of yielding a greatly increased quantity of gas on explosion. As it is decomposed by heat alone and with explosive violence if suddenly heated, it is used in dynamite in proportion much larger than that corresponding to its oxidation of the combustibles in the mixture. Ammonium nitrate absorbs water from the air like sodium nitrate, and dynamite cartridges are wrapped

in paraffined or oiled paper and dipped after closing in molten paraffine to exclude air and moisture. The effect of moisture in dynamite is to cause the separation of nitroglycerine, and the leakage of this liquid and its absorption by packages, or by the floor of the magazine, very greatly increase the danger of handling dynamite. Nitroglycerine contains more than enough oxygen for its complete combustion, and the products of its explosion are principally carbon dioxide, nitrogen, and water vapor, provided that the explosion is made with a cap of sufficient force. Like all high explosives, the nature of its decomposition depends greatly upon the manner in which it is started. It will burn safely without explosion on the application of a flame, if the nitroglycerine, or the mixture of which it is a part, is not confined or compacted in any way. The effect of a sharp blow, however, still more of the concussion produced by the explosion of another highly explosive substance in contact with it, is to produce detonation, that is, an explosion in which the rate of decomposition is at its maximum and in which the utmost energy possible is evolved in the concurrent chemical action. It frequently happens in closed spaces within a mine that men are poisoned by inhaling the fumes resulting from imperfect decomposition of nitroglycerine. The fumes in such cases invariably contain carbon monoxide, a very poisonous gas, oxides of nitrogen frequently, vapor of nitroglycerine, which is also a poison when inhaled, and sometimes small quantities of the intensely poisonous hydrocyanic acid.

A class of nitro-products of increasing commercial importance belongs to the type of nitrobenzol. These are aromatic nitro-compounds in which the substituting NO_2 is attached directly to a carbon atom. Nitrobenzols (mono- and di-) are used as ingredients of dynamite. Trinitrotoluol is much used. Of several possible compounds having this name, the one most suitable has the 1:2:4:6 structure. It is stable, of high density, easily fused, and difficult to explode by friction or percussion, while it is readily detonated by fulminate or by a cap in which the fulminate is largely replaced by the compound itself, the fulminate merely supplying the initial impulse.

By the action of nitric acid upon carbolic acid, there is obtained a substance long known for its explosive quality. Picric

acid, the substance in question, is trinitrophenol, a crystalline, yellow substance, of highly acid character, somewhat soluble in water. It fuses at 122° C., and, when cooled from fusion, has a high density, 1.65, and is more available as an explosive than the loose crystals. It is not very sensitive to shock. It contains sufficient oxygen for its own combustion, but is difficult to explode perfectly, requiring a heavy charge of fulminate and generally yielding poisonous fumes. It has been used for filling shells, but has often proven dangerous in handling. It was a component of the shimose powder used by the Japanese in the late war and of lyddite, used by the British in the Boer war. It forms salts with metals, most of which are highly explosive. Lead and potassium picrates are most dangerous, and ammonium picrate is the only one which seems reasonably safe in handling. One objection to picric acid as an ingredient of dynamite is its tendency to decompose nitrates in the mixture in presence of moisture and to form the corresponding picrates which are much more sensitive to shock.

Fulminates, especially the mercury salt, are almost the only materials used for the filling of caps or exploders by which dynamite and other high explosives are set in action. Fulminic acid is polymeric with cyanic acid, but there is no close relation between the two in structure, and it has been shown by the researches of Kekulé to contain, probably, the NO_2 group.* Mercury fulminate is made by pouring a solution of mercuric nitrate into alcohol; the product is crystalline and not dangerous to handle so long as it is moist. When dry, it is the most violent explosive that has found any commercial application. In filling caps, it is mixed with 20 per cent. of potassium chlorate.

Chlorate powders containing potassium chlorate as an oxidizer have been the subject of experiment for more than 100 years. Innumerable patents have been taken out for mixtures of chlorates with starch or sugar, or with other powdered combustible materials. Many accidents have resulted, but the subject seems to be one of perennial interest to inventors. Very recently the attempts to reduce the sensitiveness of these mixtures have met with some success in the addition of substances like oil, vaseline or paraffine, by which the different grains are enclosed in

*There is another reaction, however, which indicates that it contains the nitrosyl (NO) group. The true structure of the acid, therefore, is still unknown.

a non-combustible coating or film. A chlorate powder known as cheddite has had a limited use in Europe and 1700 tons of it are said to have been used in 1908. No powder of this class is commercially used in the United States, and none has been admitted as yet to the permitted list of the United States Geological Survey, which has national direction of the handling and use of dynamites.

Potassium chlorate is re-appearing at intervals also as an ingredient of toy fireworks and always adds to them an element of danger beyond that involved in the use of any material that is readily obtained by the public. A toy explosive containing red phosphorus and potassium chlorate was recently introduced into this country from Germany, but its sale was promptly suppressed. Potassium perchlorate is a salt which is safer for explosive mixtures than the chlorate and is also coming into use as an ingredient of dynamite, but it should be regarded, as yet, with some suspicion. Potassium chlorate has been used as an ingredient of the so-called Sprengel mixtures, suggested by Hermann Sprengel in 1873. The principle of these mixtures is that of mixing combustible matter with high oxidizers at the time and place of their employment. Such use is relatively safe. Crystals of potassium chlorate contained in a cartridge may be impregnated with a combustible oil or still more effectively with a non-sensitive explosive substance like dinitrobenzol, just before introducing into the blast hole. The materials are harmless so long as they are kept apart, but readily exploded (detonated) by fulminates after mixing. The most noted use of such materials is the material called rack-a-rock, which is made substantially in the way just described. It was the explosive used in the great blast at Hell Gate in 1892, when an immense mass of rock obtructing the channel was broken up below the surface of the water.

Among recent novelties in dynamite is the use of the powder of metallic aluminum as an ingredient. A mixture known as ammonal, and containing aluminum powder mixed with ammonium nitrate, is now in use. The very high heat of combustion of aluminum and magnesium makes them available for such a purpose, because of the large volume of gas yielded by the mixture at the higher temperature; but the expense of these

metals will probably limit their use in this direction. The common flash lights used for signalling and in photographic work, are mixtures of magnesium or aluminum powder with an oxidizer, generally potassium chlorate. Such mixtures are unsafe and should not be kept in storage.

Gases under pressure, which enter largely into commerce at the present time, involve fire and explosion risks of quite a different order than those relating to the materials above described. The following gases are now commonly sold, compressed to a greater or less degree in metal cylinders: Carbon dioxide, in the liquid state, with a pressure at common temperatures of about 600 lbs. to the square inch; oxygen, at different pressures for different purposes; nitrous oxide (N_2O), liquid, at 650 lbs. pressure; ammonia, liquid, at 50 to 60 lbs. The primary danger from these materials in case of fire is the explosion of the container because of the great increase of pressure under the action of heat. In addition to this, some of them are oxidizers (O and N_2O) which very greatly accelerate combustion, generally giving rise to dangerous explosions. Carbon dioxide is poisonous and suffocating; ammonia is suffocating and corrosive as well. In addition to these, there are chlorine, suffocating and corrosive and quickly fatal to any one inhaling it, and acetylene. The latter cannot be compressed above 75 lbs., as it becomes spontaneously explosive and is dangerous even at 40 lbs. It is an endothermic substance, and like all substances of this class, to which explosive substances in general belong, it is very sensitive to the action of heat. It is used, however, almost exclusively at present, as a solution of the gas in acetone, in which condition it is safe, so far as any intrinsic explosive quality is concerned, at a pressure of 250 lbs. to the square inch, possibly higher. In this form it is comparable to the solution of carbon dioxide in water under pressure, used in the soda fountain. The cylinders are used especially for lighting automobiles.

Some explosions and fires may be produced by water, as there are materials which react in contact with water. The most familiar of these is common lime, which, when moistened with water, especially in large masses, may accumulate enough heat to inflame wood or other combustible materials. The alkali metals potassium and sodium decompose water and evolve

hydrogen, which mixed with air ignites from the heat of the chemical action. Zinc dust, finely divided metallic zinc, oxidizes rapidly when moist and burns with great evolution of heat. Certain metallic phosphides evolve a gas, hydrogen phosphide, on contact with water, and the gas ignites spontaneously.

Spontaneous ignition from other causes: Many fibrous substances, such as hay, straw, cotton, etc., inflame spontaneously when moist and packed in masses. The spontaneous ignition of fibrous materials, rags, cotton waste, etc., which have been saturated with oil, is a surface phenomenon analogous to the latter case and is a very common cause of fires. Drying oils are most active in this way, but even non-drying animal or vegetable oils may produce the same results. Mineral oils are not subject to similar decomposition.

CHAPTER XXVI

The Handling and Storage of Combustibles and Explosives.

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Under this head are included all possible use and manipulation of these materials; ordinary uses and consumption, and all application as raw materials in manufacture. The use of these materials has so close a relation to the safety of life and property that the enforcement of any legal control over them requires as essential elements intelligent understanding of their nature and a ready co-operation of the public in the enforcement of the law.

Fire, when it passes beyond control in a dwelling, workshop or warehouse, makes so sudden a demand upon our judgment and coolness, in circumstances which are practically quite outside of common experience, that little can be expected of ordinary people other than to save themselves and the valuables nearest at hand. Effective work under such conditions is thrown at once upon the firemen and policemen, who are trained to keep their heads in such emergencies. The crisis is one in which *minutes* often determine the whole extent of the loss and the possibility of salvage. Fire control in great cities has been reduced to a system, and American cities are pre-eminent in their equipment and efficiency. Unfortunately, these very results are the enforced consequence of appalling neglect of measures which should have been taken for the prevention of fire. Our methods in this respect are painfully crude in comparison with those of European cities, and our comparative fire losses are so disproportionate to theirs that the exhibit needs only to be made to become a matter of the gravest consideration. We are proud of our fire equipment and its personnel and almost as proud of the spectacular features which go with them, but both are a painful advertisement of the neglect that has made them neces-

sary. There is nothing, however, but praise for our firemen of the uniformed force. They take upon their shoulders the whole burden of a century of neglect in fire prevention and give their lives often in taking risks that municipal administration is entirely responsible for.

The systematic study of the conditions that lie at the base of fire prevention has been practically neglected. The principles which they involve are almost purely scientific and worthy of the best training and experience of scientific men in their investigation. They have been regarded only as so-called "practical" details which will work themselves out in the ordinary run of experience; but this is the familiar method which has so often applied rule-of-thumb usage to conditions which have long outgrown them. Railway management that should follow the same methods would discard the civil engineer, and commit the designing and building of bridges to blacksmiths. The only systematic work that has been done for our cities in the line of fire prevention and its study has been done by interests quite outside of municipal control. First of all, the insurance interest has long made use of monetary pressure to secure the co-operation of the public in this line. Advancing premiums are arguments that everyone understands. As the first workers in this field, the insurance companies deserve first credit.

On higher lines and by much better application of scientific methods, investigation towards fire prevention has been going on under two different authorities. The United States Geological Survey has recently begun a systematic study of these questions, and the Pittsburg Station of the Technological Branch of the Survey is collecting data and conducting experiments by experts into the very elements of our Municipal Fire problem.

The Bureau of Explosives of the American Railway Association, with headquarters in New York, is doing accurate work of the same kind in the interests of transportation. But the great city of New York and a dozen other large American cities have scarcely taken the first step in this same kind of study. We have fire laws and have had them for many years, but the enforcement of them lacks the feature of trained and intelligent direction. To show the facts of the case, some figures recently published by the United States Geological Survey are of interest.

TABLE I.

Statistics of Fire Losses from Report of U. S. Geological Survey, Bull. 418.

Loss per capita in 2,976 American cities and towns (pop. 34,102,453) in 1907	$ 2.51
Loss per capita in six European cities	.48
Loss in European countries, per capita	.33
Annual loss by fire in the United States, including fire department and expense of maintenance	456,486,151.00
Capital invested in fire protection in U. S.	402,735,200.00
Total loss in 1907 on buildings in towns and villages	50,173,625.00
Total loss in 1907 on buildings in country districts	58,983,269.00
Loss on brick, stone and iron buildings, towns and villages	19,818,474.00
Loss on contents of same	11,072,570.00
Loss on brick, stone and iron buildings, country districts	11,276,213.00
Loss on contents of same	8,240,310.00
Loss on frame buildings in country districts	47,707,056.00
Loss on contents of same	40,707,847.00
Loss on frame buildings in towns and villages	30,357,151.00
Loss on contents of same	27,827,388.00

The aggregate annual fire loss per capita in 1907 in 2976 cities and towns of the United States, embracing a population of 34,-162,452 inhabitants, almost half of the population, was $2.54. The average cost per capita for fire losses in eight large European cities was forty-eight cents ($0.48). For Germany alone, the loss per capita in the cities selected was only 25 cents, and Germany is pre-eminently the country of the world that is putting science into its business methods. The case is still further emphasized when we consider that the equipment for fighting fires is better in American cities than anywhere else in the world; and yet, with these advantages, our losses compared with European cities are as five to one. The primary cause for this state of things is the predominance of wooden buildings in the United States, and their almost entire absence within city limits in the larger cities of Europe. The fire loss also is shown by these statistics to be practically doubled by the outlay in fire-fighting equipment of every kind. The mere capital invested in the fire equipment of American cities is about equal to the annual fire loss and nearly one-half of the value of all of the new buildings constructed in the country in a year is lost annually by fire. The expenses of maintaining fire equipment, as well as interest, depreciation, taxes and insurance, are charged to fire losses in this estimate. Losses by fire in cities are slightly less per capita than those in country districts. The want of fire protection in rural districts, which should give them a much greater ratio of loss, is overbalanced by the concentration of combustibles and

their accompanying risks in the cities. A study of fire prevention as it exists in American cities is a difficult matter, because systematic classification of the origin of fires and of the sources of loss has never been made. We depend for these data upon official reports of superintendents and fire marshals, and these are painfully lacking in the elements of precision and accuracy which make the whole value of statistics. Fire insurance companies have collected, perhaps, more of such data and with more care than any of the parties interested; but city officials who should be most of all concerned in filing accurate details upon which all progress must be based, have seemed to regard the matter as anyone's affair but their own. With the idea of getting some data upon the single subject of explosions, regardless of accompanying fires, the writer collected for eleven months, included in the years 1908-1909, through a newspaper clipping agency, three hundred and fifty-two items relating to explosions in ten different American cities. Such items do not come with the highest authority, but in many cases they are the only data that can be secured, and at least they must bear with a fair degree of uniformity upon explosions from different causes. Out of the entire list of explosions, 41 per cent. were due to gas explosions, principally illuminating gas, due to leakage; and 28 per cent. were due to explosions resulting from the use of volatile liquids, principally gasoline and benzine. In the items of explosions alone, therefore, these two sources represent almost 70 per cent. The sources of the other explosions were much fewer; accidents from blasting and fireworks ran high, and from bombs or high explosives used with criminal intent the list was almost as large.

TABLE II.

Sources of Explosions in American Cities, Collected from Newspapers, eleven months of 1908-9 (352 cases, 252 in New York).

Gunpowder, dynamite and fireworks	9 %
Bombs (explosions with criminal intent)	8.5%
Gas explosions	28 %
Volatile liquids (vapor of)	41 %
Drugs	4.5%
Unclassified	8 %
	100%

Taking up now, in the order in which they have previously been treated, the *different materials concerned in the fire risks,* let

us consider their relation to actual fires as experience has shown it, and the means of handling them which will best contribute to fire prevention. The class of *oxidizers* includes, strictly, many other chemical substances, but the term is used here to cover only those which are in common use and which give up oxygen very readily when heated or in contact with organic matter under pressure or concussion. The especial danger of these materials is less that they originate fire than that they greatly accelerate fire already started. In the earlier stages of the fire, before the firemen have arrived, this sudden increase in temperature is a serious matter. At a later stage, their effect is often to add the element of explosion to the dangers that threaten the fire workers. All of the peroxides are dangerous in this sense, and those of sodium and potassium are additionally so because they liberate oxygen by contact with water. The latter are packed, however, as a rule, in small metallic cases hermetically sealed, the cases being enclosed in groups in wooden boxes.

Chlorates and permanganates are kept as loose crystals and generally in wooden packages. Metallic packages are preferable. Whether these packages are broken by falling or burst through the action of heat, the effect is the same when a fire has attained headway, and violent explosions result. If the materials are scattered before they are heated, they render explosive all organic material with which they mingle, provided the mixture is heated later, and it is always possible that impact may bring about an explosion without the direct action of fire. The question whether chlorates, especially potassium chlorate, the one most commonly used, are explosive in themselves, is an open one. Potassium chlorate is an endothermic substance and in theory is explosive. Accidents have resulted which could bear no other interpretation than direct explosion of the salt, but it is to be remembered that organic dust is always present and very little of this is required to make, with the dust of a chlorate, an explosive mixture. It is of interest to know that strong percussion upon pure potassium chlorate enclosed between platinum foil, produces a separation of chlorine as indicated by silver nitrate. In mills where chlorates are ground, dust of these salts is very apt to produce explosive mixtures with organic dust and to ignite under the concussion of machinery.

Nitric acid, especially if packed, as it commonly is, in carboys surrounded by straw, is very dangerous in case of breakage or heat. Upon straw or excelsior or paper, it produces flame after a very short contact. An effort is now being made to pack carboy boxes with a non-combustible material. All of the common strong acids involve fire risk, even if they are not oxidizers. Sulphuric acid (oil of vitriol) produces heat by absorption of water, and, under certain conditions, may yield oxygen. Hydrochloric acid may set up chemical action with other materials, which results in heat. Under city conditions, it is better that all of the oxidizers should be stored in cellars and apart from combustibles. They will be less exposed to the sweep of flame because the influence of air or other gas currents is less; they will not fall upon other materials, and they are certain within a short time, in the positions in which they are most apt to occur, to be thoroughly drenched with water when the fire attack has begun.

Apart from the oxidizers, which add an uncertain element to every conflagration, the danger rests mainly in the degree of combustibility of materials and upon their subdivision. Fibers of all kinds, packing materials or textile fibers, especially when loosely disposed, are most readily inflammable. Among textile fibers, wool and silk are much less inflammable than cotton. Wooden packages of all kinds, when empty, are almost of equal danger. Tar, pitch, rosin, and asphalt quickly evolve combustible vapors when heated and belong to the materials that contribute flame and have most to do with propagating fires. Combustible dusts are still more dangerous because, when diffused in the air, they produce dust explosions which are as violent as gas explosions and of greater igniting effect.

Classification is the essential consideration in warehouses where combustibles or oxidizing materials are stored. Combustibles should be stored above ground, the lighter materials at the top. Volatile liquids of the more expensive class, ethers, etc., should be kept in small, separate fire-proof vaults, if possible outside of the walls of the building and under the sidewalk or an interior open court. Materials that are especially dangerous, like phosphorus, alkaline metals, etc., are best kept in bottles enclosed in metallic, closed boxes and these, preferably, im-

bedded in sand. The element of time is to be considered in all classifications for storage. Flame or heated air is the agent of propagation. Radiation from glowing surfaces comes later and acts only at short distances. Compact masses are slowly attacked by fire and the impeding of draught is of the first importance in checking the progress. In construction of a building, cement walls and floors are first in fire-resisting quality; subdivision by brick or cement walls facilitates classification and may often confine a dangerous fire to the compartment in which it originated. Wooden timbers are not as dangerous, except at advanced stages of a fire, as they might seem to be. Oak pillars may be charred to a considerable depth and yet prevent for a long time the collapse of the floors that they support. Pine and resinous woods give off combustible vapors more readily under heat and are more quickly disintegrated. Fire doors of wood covered with tin-plate are often more effective than thin doors of iron because of their non-conducting quality. But all considerations relating to the spread of fire depend upon the relative speed and activity which may be expected in a fire-fighting force. In the heart of a great city, under present conditions, the presumption of its prompt action is a useful guide in the storing and classification of different materials.

Gases and vapors are the materials by which, especially, fire is spread. And next to these, although less common, are combustible dusts. Illuminating gas, mixed with air before ignition,

TABLE III.*

Ignition points of gases in air.

Carbon monoxide (CO)	636-814° C.
Marsh gas (CH_4)	656-678° C.
Ethylene	605-622° C.
Carbon disulphide	100-170° C.
Acetylene	509-518° C.
Coal gas	647-649° C.
Oxyhydrogen gas	620-700° C.
Hydrogen	555° C.

produces explosions and the shattering force of these may very much assist the subsequent fire. In such an explosion the force involved is enormous, and doors and windows are merely safety valves which prevent the entire wreck of heavy structures. A gas explosion may have little igniting effect if readily inflam-

*Von Schwartz: "Fire and Explosion Risks," p. 33.

mable substances are absent; but dust explosions carry a high heating effect and invariably leave fire in their wake.

Compressed combustible gases are so dangerous as to be properly classed among explosives. Slight increase of temperature, even by prolonged exposure to sunshine, has caused the containing cylinders to explode. Compressed acetylene is explosive *per se,* but its use in acetone solution under pressure has, so far, been found reasonably safe. Ammonia, sulphur dioxide, and carbon dioxide, all extinguish fire, and are very effective in preventing the ignition of combustible gases. Compressed oxygen, like the oxidizing chemicals, chlorates, etc., would produce explosions where combustible matter was present at a sufficient temperature. All suffocating gases, such as chlorine, carbon dioxide, ammonia, and sulphur dioxide, although they extinguish flame, are of serious disadvantage in case of fire because they interfere with the work of firemen. Combustible vapors are to be classed with gases, and in case of fire produce explosions. Volatile liquids, gasoline, benzine, alcohol, ethers, acetone and carbon disulphide, are, next to gases, the materials which originate fire. The vapors of these liquids are from three to six times heavier than air and flow like water along the floor of the building to reach a source of ignition from which they flash back to the container from which they may have leaked. And if not ignited at once, they diffuse in the air and make explosive mixtures which become more dangerous as the moment of ignition is farther removed. Carbon disulphide is more dangerous in respect to its low igniting point than any commercial liquid. Alcohol, wood spirits and acetone are preferably stored in cellars if the building contains a miscellaneous stock, and barrels should never be arranged more than two in depth.

Benzine, gasoline and the light tar oils should be stored in open lots, preferably under cover and, unless in very large quantities, in underground tanks. The automobile industry has added an entirely new menace to property within the city in the handling of volatile liquids. When every block along a city street may carry a larger garage with its tank of gasoline, the precautions against fire require quite an exceptional observance. The regulations in New York City prescribe minutely the location and the capacity of the tank, the maximum quantity to be stored, the

conditions of pumping and transfer in filling the tanks of automobiles, and, in spite of the threatening character of the industry, make it reasonably safe, provided these places are kept under proper inspection. The interest of the owner of a garage is so seriously connected with the observance of these regulations that much may be expected from his co-operation. But supervision is none the less necessary. The escape of gasoline from these buildings into the sewers has given rise to several serious explosions in sewers in New York, sometimes at considerable distances from the garage center. From an investigation of one of these explosions, I was satisfied that escape of gasoline is very common and that the infrequency of explosions is due rather to the infrequency of opportunities of ignition of the mixture of air and vapor in the sewer. When an explosion occurs at a given point in a sewer, it is common to have a succession of explosions, sometimes at considerable distances, and without evidence of excessive pressures at points between the two locations. In this case the later ignitions are probably due to the forcing of explosive mixtures, under pressure of the first explosion, into the tunnels of the underground electric trolley system, where they are ignited and made to flash back into the sewer. No fatalities have resulted as yet from these sewer explosions, but there have been many injuries and many narrow escapes from death. Fires on automobiles result from escape of gasoline vapor or liquid, the ignition of which about the tank produces in time an explosion of the tank, under pressure merely, with a scattering of burning gasoline. In motor boats the same causes occur with the same results. Every auto and motor boat should carry a small fire extinguisher, which could readily control the flame in the time intervening between the first ignition and the bursting of the tank. The consequences of the latter are most serious. Smoking in motor boats and even about the pier ends where gasoline is supplied from tanks, is more common than would be supposed, and it is remarkable that more accidents do not occur. Empty barrels that have contained volatile liquids are a common source of explosion. When these are ignited by flames applied in any way near the bunghole, the explosion is sufficient to shatter the heaviest barrel.

TABLE IV.*

Range of Explosive Proportion in Mixtures of Combustible Gases or Vapors with Air.

Carbon monoxide (CO)	13-75%
Coal gas	8-23%
Hydrogen	7-75%
Carbon disulphide (CS_2)	6% and below
Ether [$(C_2H_5)_2O$]	6% and below
Acetylene (C_2H_2)	3 to 82%
Benzol (C_6H_6)	3 to 6%
Pentane (C_5H_{12})	2½ to 5%

The question of *dust explosions* is worthy of further attention. When combustible powders are finely divided and suspended in the air, they become like mixtures of combustible gas and air and ignite in the same way on contact with flame. The rupturing effects are greater than in gas explosions and the heat is greater. Many accidents have occurred in factories and in mills where combustible dusts are set free in working. The bursting of a bag of starch or sugar powder in a warehouse has given rise to the same kind of explosion. It is essential to such explosions that the dust be fine and that it fill the air so that its particles are relatively near together. An element of the explosion, also, is the disengagement of combustible gas from the heated dust and this serves to convey the heat from particle to particle and so to propagate the flame. The action, however, is almost instantaneous over great distances. Flour mills are particularly liable to these accidents and the chutes or passages through which flour is conveyed are ready channels for carrying the explosion from one part of a building to another. It generally occurs that a small initial explosion in a room fills the air of adjacent rooms or floors with dust and leads to successive explosions of increasing violence. Five large mills were wrecked and entirely destroyed by dust explosions originating in one of them at Minneapolis in 1878. There have been many such explosions, notably one in this city in a confectionery factory on Barclay Street, about 1890, in which several lives were lost. The explosions of dust in coal mines are very common and are assisted by the presence of combustible gas; it is even possible for non-combustible dust to produce explosion in a mixture too poor in combustible gas to be of itself explosive.

*Von Schwartz: "Fire and Explosion Risks," p. 34.

Metals in fine powder can also produce dust explosions; aluminum, magnesium and bronze powders have been known to cause these explosions. Zinc powder is peculiarly susceptible to oxidation. It may produce dust explosions and in mass it heats up very readily when slightly moist. I know of a case in which a cask of this material became slightly damp during transportation and was delivered at a factory with fumes issuing from a crevice in the cask. It burst into flame on being opened and glowed with an intense heat for many hours. Lump sulphur kept in bulk or in barrels, is only dangerous after melting, when it begins to evolve vapor. Flowers of sulphur, the powdery form, readily produces dust explosions. Its mixture with potassium chlorate, which is often used in fireworks, is apt to be spontaneously explosive; the effect is due to free sulphuric acid, which is contained in minute quantities in all flowers of sulphur. Red phosphorus is not affected by moderate heat, but is transformed into yellow phosphorus at 260° C. and then burns rapidly. Mixed with oxidizers like potassium chlorate it forms one of the most dangerous explosives and can only be compared to mercury fulminate. Lycopodium, the fine spores of a species of lichen and a common article in the drug trade, is especially dangerous as a source of dust explosions.

Among commercial materials that are stored together, especially in drug warehouses, there are many that prevent combustion. These are either substances that are fully oxidized or that have no affinity for oxygen under ordinary conditions. We have already considered some of these in speaking of compressed gases. These gases, ammonia, sulphur dioxide and carbon dioxide, are sometimes introduced at normal pressures by pipes to arrest incipient fires just as is done by sprinkling systems. They are useful, however, only at an early stage of the fire. When masses of material are burning, the speed and volume of air currents that are set up diffuse these materials too rapidly to permit of their action. When introduced for this purpose, they should be put in near the floor, as they are heavier than air, and if supplied in sufficient quantity will cover the burning surfaces and float away the supply of air. Carbon tetrachloride is a liquid closely related to chloroform, very heavy (sp. gr. 1.6), and yields a vapor that is five times as heavy as air. It is

a most effective fire extinguisher and is coming into use for portable fire apparatus. At a strong heat it decomposes, yielding hydrochloric acid and free carbon. Its fumes are objectionable in odor and have anæsthetic properties. It is to be used, however, like the gases above mentioned, only for dealing with incipient fires. A mixture of combustible gases or vapors with these non-combustible gases is non-explosive even when the latter are in relatively small proportions.

TABLE V.*

Per Cent. of Carbon Dioxide in Air to Render Gases Non-Combustible.

Combustible Gases.	Per cent. of Carbon Dioxide in Air.
Marsh gas (CH_4)	10%
Candle flame	14%
Paraffine oil (kerosene)	15%
Carbon monoxide (CO)	24%
Coal gas	33%
Hydrogen	58%

Fire extinguishers are of many forms and depend either upon the projection upon the burning materials of a liquid yielding a non-combustible gas or vapor as described above, or of a strong solution of some mineral salt which has the effect of coating the burning surfaces with a non-combustible film as the water evaporates and so shutting off the supply of the air. The most effective of these latter are the solutions of ammonia salts, phosphate and sulphate especially. These yield ammonia at the burning surface, which extinguishes the fire, and they partly contribute an acid residue which also stops combustion. A common type of apparatus is one which carries a strong solution of a mineral salt and in another compartment a solution of sodium carbonate which can be mixed at will with sulphuric acid, contained in an adjoining reservoir. The saline solution is driven out under pressure of carbon dioxide produced in this way. Cheaper and more common are the so-called fire grenades, which are angular and rather thin bottles containing strong saline solutions of ammonia or alkaline lime or magnesia salts, which break when thrown by hand, coating the surface of burning material with a mineral film and quenching it through the cooling effect of water. All of these extinguishers are temporary devices, but they are very effective in that they can be used by any one, and they either quench the fire completely or check it

*Von Schwartz: "Fire and Explosion Risks," p. 76.

until more efficacious means can be brought to bear. They are among the simplest and most practical forms of fire prevention.

Explosive Materials themselves are of comparatively little importance as affecting fire risks in cities except as they relate to blasting operations in foundation and tunnel work. The sale of gunpowder and sporting powder is relatively small. They are sold in a few places and are not difficult to control. Fireworks are a much more serious menace, but the danger is confined almost entirely to a short period about the Fourth of July and there is a strong tendency to confine their use to public exhibitions managed by trained men. The manufacture of fireworks is forbidden entirely in the boroughs of Manhattan and the Bronx, and is permitted only under conditions allowing abundant separation of the different operations in the other boroughs of New York City. The most dangerous part of the sale of fireworks is in the handling of them in small retail stores during the short period of the permit, and this is not likely to be permitted in future.*

Blasting in New York has to do mainly with hard rocks more or less crystalline, and none but high explosives of the dynamite class find much use. The dynamite question is always a pressing one in cities because of extensive blasting required. This is especially so in New York City. Its control is minutely prescribed in the regulations of the Municipal Explosives Commission. The construction of magazines, the quantity of dynamite permitted for each class of work, the depth of hole, weight of charge, quality of lagging or covering to prevent flying of fragments, and the restriction of blasting to the hands of certified men who have had experience in the work, will suffice to prevent accidents or injury to adjacent buildings if the supervision is always adequate. There is no phase of city work which needs more careful inspection than this, and it is certain that it has not always been adequately inspected. Inspectors for this work should be in all cases men who have had some experience either as blasters or inspectors of blasting. To put untrained men at such work is useless and dangerous. During the building of the first subway immense quantities of

*As this goes to press it is gratifying to state that a sane Fourth has been celebrated in N. Y. City. No fireworks permits were allowed retailers. There was a notable decrease in casualties.—C. B.

dynamite were used, and it was remarked at that time by someone that New York was "the greatest mining camp in the country." The quantity of dynamite in daily use in this small area was enormous. No notable accidents with dynamite occurred except the great explosion near Forty-second street in the Park Avenue section of the tunnel in 1902. This explosion, however, was so serious in its effects that it led to the establishment of the Municipal Explosives Commission, which was charged with framing of regulations for the control in general of combustible and explosive materials, and its regulations have been since that time the law under which these materials are used.

When dynamite is used at the rate of several tons a day within the city limits, it is a serious question how it shall be disposed of in *magazines* to secure the greatest safety. Allowing only for a daily supply on hand at any one time, there is still the necessity of storing very dangerous quantities of explosives on the line of built-up streets. It is a question whether it is best to have a few large magazines or many small ones. The larger magazine can be as effectually watched as the small one, but it involves more detailed supervision and the necessity of carrying small quantities of powder more frequently to the point of work, which at times is relatively much farther away. Having always in view, however, the effect of an explosion of the whole mass with its appalling consequences in a thickly settled district, it seems better to subdivide the mass and have smaller magazines at more frequent intervals and nearer the work. Either of the plans, nevertheless, depends upon conditions for its superiority. Large, deep open cuts and great excavations improve the conditions for handling dynamite. Magazines are preferably of light construction for these local uses so that they may not supply heavy and dangerous fragments to be scattered in case of explosion. They should be covered thickly enough to prevent accidents from flying fragments coming from without. Probably the best protection for this purpose would be the heavy rope mattresses now used in blasting.

All regulations for the control of combustible and explosive materials depend more upon the quality of the inspection than upon any other condition. The work of an in-

spector demands activity, intelligence and honesty. And with these as a basis and technical training in the officials who direct them there is no difficulty in securing inspection of a high order. The regulations should be full enough to leave little to the discretion of the ordinary inspector. Too great latitude in this direction is a fruitful source of inefficiency and corruption. There is no employment in municipal service that can more affect the quality of government than the work of the inspector. He should be carefully selected, well paid and held to the highest accountability.

CHAPTER XXVII.

Paint.

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Painting as a decorative art goes back to very ancient times. We find that the Aborigines decorated their persons with pigments and that the Egyptians used pigments in decorating their temples, for in the ruins of the Temple of Karnak in Egypt there are still decorative paintings on the walls and on the pillars more than 3,000 years old.

Protective paint, by which is meant paint used for the purpose of the protection of the surface to which it is applied, is relatively new, and in Europe building construction was of such a character, and is largely of such a character today, that paint is not used to any great extent on the interior of dwellings. Only in a pioneer country like America, where domiciles were made of wood, was it found necessary to apply an exterior coating to preserve the wood.

For decorative and preservative effect, we find more evidence of the use of paint in England than we do in any other country.*

Up to the latter part of the 14th century, however, oil painting for artistic purposes was not an exact art, and to Hubert and Jan Van Eyck, two Dutchmen, belongs the credit of first having

*There are items of expense in the Reign of Edward I. showing the use of paint, as follows:—

In the period from 1274 to 1277 (2d to 5th of Edward I.), an account, apparently relating to the Painted Chamber, contains the following items:—"Reymund, for seventeen pounds of white lead ii.s.x.d. To the same for 16 gallons of oil, xvi.s. To the same for 24 lbs. of varnish, xii.s. To Hugo le Vespunt, for 18 gallons of oil, xxi.s." Again: "To Reymund, for 100 leaves of gold, i.li.s. To the same, for 22 lbs. of varnish, xi.s. I.d. Elsewhere, to Robert Kinf for one cartload of charcoal for drying the painting in the King's hamber, iii.s. viii.d." The last entry appears to relate to the drying of surfaces painted in oil, but the precaution may also have been necessary before varnish tempera. The application of heat, even before painting in oil, according to the directions of Eraclius, will here be remembered: "Ad solem vel ad ignem siccare permittes." It can hardly escape observation, that the practice of oil painting taught by Eraclius agrees in many details with that exemplified in the English records; and the circumstances may warrant a supposition that he composed his treatise in this country. 1289 (17th of Edward I.). The following materials are enumerated in an account relating to repairs in the Painted Chamber:—White lead, varnish, green, oil, red lead, tin-foil, size, gold leaf, silver leaf, red ochre, vermilion, indigo, azure, earthen vessels, cloth, etc.—Eastlake's "Materials for a History of Oil Painting."

made public their manner of oil painting by means of pigment ground, as near as we know, in linseed oil.*

Occasionally we hear a complaint that the pigments made nowadays are not as good as those that were made in former years, and the poverty of our pigments is the cause of the early decay of many of our paintings. An error of this kind deserves correction, for the art of the manufacture of colors has never reached a higher plane than it has at present, but to ignorance of painters and to the greed of paint makers must we attribute the fugitiveness of our paintings. Between the 12th and the 17th century there existed at most only 9 or 10 pigments. Today we have 215 or more, 200 of which ought never be used for permanent artistic painting. The ancients used black, green, brown, vermilion, blue and white, nearly all of which were composed of minerals that were absolutely permanent; and before the use of oil painting, tempera painting had held its sway for over 1,000 years. This was a mixture of pigment with the white of egg and water, and when that was dry no further chemical effect took place.†

It is not within the scope of the subject to discuss the incompatibility of pigments, but reference must be made to the fact that there are many pigments which destroy each other and which are otherwise permanent. If we take, for example, yellow ochre, which is extremely permanent, and madder lake, which is also permanent, and mix them together, we have in the course of a few months a destructive effect in which the entire appearance of ochre is changed and the brilliancy of the madder is eradicated.‡

*It is a fact worthy of mention, that there is one painting in the National Art Gallery in the city of London by the brothers Van Eyck which is in as perfect a state of preservation as if it had been painted yesterday.

†The ancient pigments were as follows:—white lead, chalk, and calcium carbonate. There are some instances where tin and zinc oxides were also used. Black was produced by the cooling of a smoke flame, which produced pure carbon, and was equivalent to our lampblack.

Green (a): the hydrated carbonate of copper, which is the mineral malchite; Green (b): terra verte or green earth, which is a clay stained with iron.

Red: bright oxide of iron, or native Indian Red.

Vermilion (a): Synopia or Zinnobae, which was the native vermilion found in Idria, and selected according to shade; Vermilion (b): the artificial Chinese vermilion brought to the West by Oriental travelers.

Olive Green: native umber. Brown: burnt sienna.

Yellow: Ochre and native Sienna. Blue: Lapis Lazuli, or natural ultramarine.

‡Incidentally it may be remarked that this was the cause of the failure of nearly all the paintings of Sir Joshua Reynolds, who, in search of the supposed secret of the old masters, mixed these two colors, with the result that most of his paintings decomposed in a short time, not through the action of light, but through the effect of the hydrated oxide of iron on the madder lake.

When we ordinarily see a painter with a pot of paint and brush painting either a steel or wooden structure, we imagine without further thought that that is the use to which paints are put. As a matter of fact, paints and colors are used in enormous quantities in the arts and sciences for purposes other than decorative or protecting painting. Below is a list of the purchases of the Bureau of Engraving and Printing, Washington, D. C., for the year 1910, showing the actual contract for 1,599,900 pounds of pigments:

	Lbs.
White	802,200
Black	297,500
Blue	52,000
Green	180,000
Red	68,200
Yellow	200,000
	1,599,900

These pigments are identical in every respect with the paints used for general painting, and yet all these pigments are used for the purposes of printing the currency and the postage stamps of this Government. The printing ink industry in the United States consumes enormous amounts of paint. In some instances the paint is ground in a varnish made of linseed oil, though for book ink and newspaper ink linseed oil is not used, but resinous mediums which act as a binding material for the pigment. The floor oilcloth and table oilcloth industries are also enormous users of paint in the strict sense of the word. While it is true that the mixtures which they make differ from the house painters' mixtures, for their paint must be baked on and cannot be rolled if allowed to dry in the air, yet the principle involved is identically the same as that of ordinary paint. The shoe and leather industries are users of paint materials in large quantities for making patent leather and harness leather, and so are the wall-paper industry, the window shade industry, the rubber industry and the cement industry. Their color effects are more or less dependent on the same pigments that are used for ordinary painting.

In the strict sense of the word, paint which is used on concrete, steel and wood is an engineering material, and serves a purpose which is far more valuable than we imagine. Take the case of any one of our bridges across the East River, and ask

yourselves the question, how long would they last if they were not painted and if they were not continually kept painted? We had a sad experience some years ago on the Brooklyn bridge, when one of the buckles supporting the cable snapped, because it had not been kept properly painted. The bridge over the Firth of Forth, which is the largest bridge in the world, is continually kept painted. A gang of men start at one end, and when they reach the other end they begin over again. This important topic will be considered in our next chapter.

Paint is essentially a pigment, a pulverulent solid, which may or may not be colored, but possesses hiding power, which may or may not affect the surface of the material to which it is applied, suspended in a liquid, the vehicle, which, on evaporation, drying, or by certain chemical changes, serves to bind the pigment to the painted surface and thus protect it.

The pigments used in ordinary general manufacture of paints are as follows:

White Lead.
Lead Sulphate.
Lead, White Sublimed.
Standard Zinc Lead White.
Zinc Oxide.
Lithopone.
Red Lead.
Blue Lead Sublimed.
Venetian Reds.
Indian Red.
Permanent Vermilion.
Orange Mineral.
Para-Nitraniline Lake.
Burnt Ochre-American Sienna.
Chrome Yellow.
Ultramarine Blue—Cobalt Blue.
Artificial Cobalt Blue.
Prussian Blue.
Chrome Green.
Chromium Oxide.
Lampblack.
Carbon Black.
Graphite.
Charcoal.
Coal.
Mineral Black.
Vine Black.
Silica—Infusorial Earth.
China Clay—Kaolin.
Barium Sulphate.
Barytes.
Calcium Carbonate.
Gypsum—Terra Alba.
Whiting (White Mineral Primer).
Quicksilver Vermilion.
Prince's Mineral.
Prince's Metallic.
Ochre.
Umber.
Sienna.
Vandyke Brown.
Lakes made of coal-tar colors.

The coal-tar colors have practically superseded the old-fashioned wood lakes, and even madder lake is today made from alizarine and not from the red of the *rubia tinctoria* of the madder plant.*

*France placed a premium on the cultivation of the madder plant and ordered the trousers of the French army dyed with madder in order to give that industry an impetus; but when alizarine, which is a coal tar dye of the same composition as madder and every bit as permanent, was invented, the madder industry declined, even though the French army is still clad in its madder uniforms.

The antiquated way of making the lake colors is to take the dye woods, like brazil wood, logwood, hypernic, persian berry, etc., and precipitate the dyestuff contained in the extracted liquor with tin chloride; but since the coal-tar colors* have been invented there are very few dye wood lakes made, nor were the wood lakes any more permanent than the coal-tar color lakes which came after them.

Within the last twenty-five years coal-tar color lakes have been invented which are regarded as permanent, and many of these, such as the paranitraniline lakes, the paratoluidine lakes and alizarine, are made by the development process.

A full description of the pigments and the methods used in their manufacture would occupy more space than has been allotted me.† Important principles involved in their use may be illustrated, however, by considering a few of the most important pigments. These principles are concerned with the crystalline structure of the pigment, its fineness of subdivision, what is known as chalking, and the influence of the addition of inert diluents or extenders. Modern research has shown that a suitable mixing of particles of different degrees of fineness of one pigment gives better results than if the particles are of essentially the same size. It is not long since that the addition of, for example, barium sulphate to white lead was regarded as an adulteration. And so it was, when such a mixture was sold as "white lead," but the most careful investigations have shown that in many cases the addition of diluents, as barium sulphate, silica, and clay, actually improves the quality of the paint. Such additions, however, should be made only by the expert paint manufacturer, whose knowledge has been gained by experience and oftentimes at great expense in labor and research. Photomicrographs bring out these facts, as may be seen from the illustrations.‡

White lead is the oldest of all white pigments, and prior to the middle of the last century it was the only white pigment in use

*These are often erroneously called "anilines." Such a term is misleading, for they are by no means all derived from aniline.

†*Vide* "The Chemistry and Technology of Mixed Paints," by the writer. Van Nostrand & Co., New York.

‡Very elaborate comparative experiments have been and are being carried out at considerable expense by the Paint Manufacturers' Association of the United States under the direction of an eminent Consulting Board and experienced experts. Tests on a large scale are in progress at Atlantic City, Pittsburg, and in North Dakota, where the widest ranges of climatic and atmospheric differences are met with. The reports of these experts may be had on request. We are indebted to the Association for many of the illustrations.

with the exception of a little zinc and bismuth. Within half a century quite a number of other white pigments have come into use, and only gradually have the defects of white lead become known.

White lead is in great favor with the practical painter, not for its wearing quality but principally for the freedom with which it is applied. Although white lead is generally spoken of

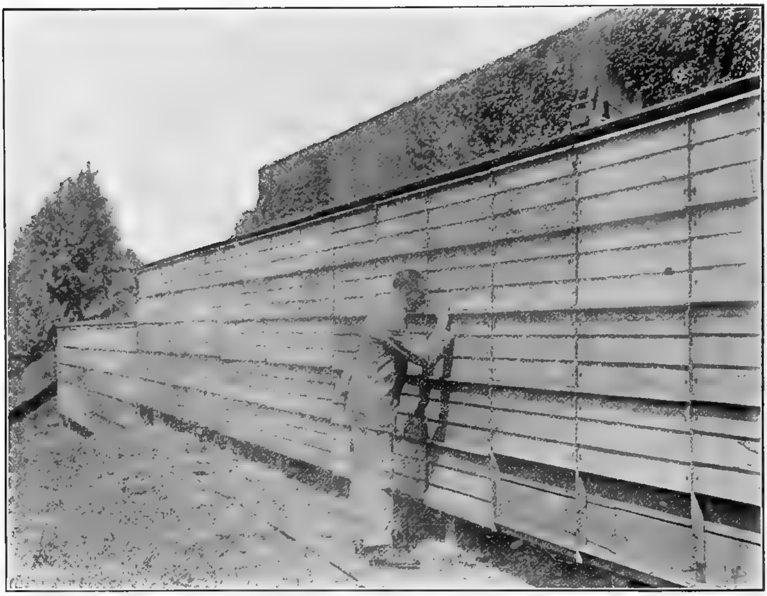

FIG. 220.—INSPECTOR EXAMINING THE PITTSBURG TEST FENCE. SIMILAR TEST FENCES WERE ERECTED IN NORTH DAKOTA AND AT ATLANTIC CITY, N. J.

(Taken, by permission, from *Bulletin* No. 28, of the Scientific Section of the Paint Manufacturers' Association of the U. S.)

as a carbonate of lead, it is composed of approximately 69 per cent. carbonate of lead, $PbCO_3$, and 31 per cent. of lead hydroxide, $Pb(OH)_2$. It is the lead hydroxide which combines quite rapidly with oil and forms an unctuous substance sometimes known as "lead soap." White lead is variable in composition, the amount of hydrate ranging from 15 to 30 per cent. In addition to this, during the process of manufacture of the old

process lead, and after its final washing, it is mixed with linseed oil while still in the wet state. The oil having a greater affinity for the white lead than the water has, the latter is displaced. A

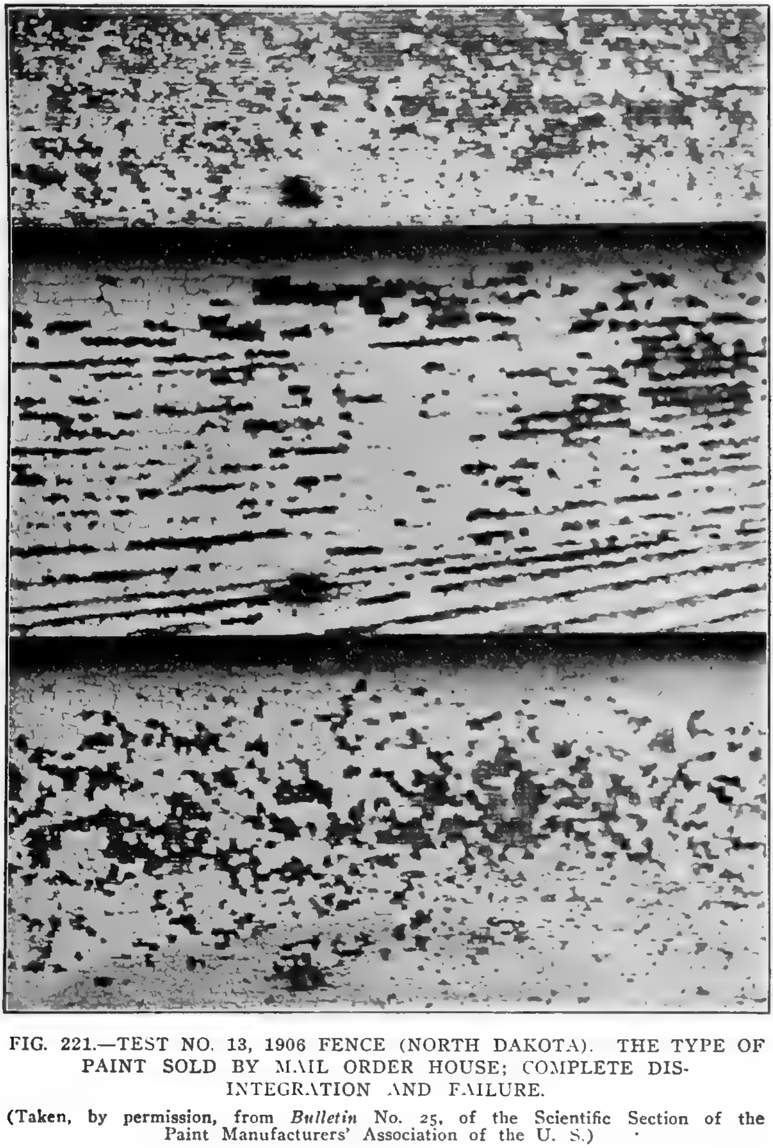

FIG. 221.—TEST NO. 13, 1906 FENCE (NORTH DAKOTA). THE TYPE OF PAINT SOLD BY MAIL ORDER HOUSE; COMPLETE DISINTEGRATION AND FAILURE.

(Taken, by permission, from *Bulletin* No. 25, of the Scientific Section of the Paint Manufacturers' Association of the U. S.)

small percentage of moisture adds to the free working quality of the paint made from white lead.*

The ratio of oil necessary to reduce white lead to the consistency of paint can by no means be given in exact figures.†

No general rule can be given for the percentage of oil necessary, as temperature has much to do with this, but the difference in the amount of oil necessary to produce a good flowing paint during summer or winter can be approximately given as 10 per cent., less vehicle being necessary in summer than in winter.

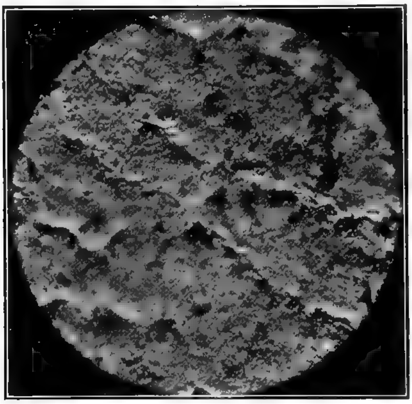

FIG. 222.—FORMULA 36, ATLANTIC CITY TEST FENCE; PURE CORRODED WHITE LEAD AFTER FIFTEEN MONTHS.

(Taken, by permission, from the Special *Bulletin* for Engineers, et al., of the Scientific Section of the Paint Manufacturers' Association of the U. S.)

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*White lead is regarded as a poisonous pigment, and so it is, but this property should not condemn it for application to the walls of a house or for general paint purposes, because its toxic effect cannot be produced from a painted surface. Its poisonous quality is manifest to the workmen in the factories where white lead is made, and also to the painter who is careless in applying it. The unbroken skin does not absorb lead very rapidly, but the workmen inhaling lead dust, or the painter who allows a lead paint to accumulate under his finger nails, is likely to suffer from lead poisoning. In one or two factories where much white lead is ground, a small percentage of potassium iodide is placed in the drinking water. This overcomes any tendency toward lead poisoning, by reason of the fact that the soluble iodide of lead is formed in the system and the lead is thus flushed out through the kidneys. Charles Dickens, in one of his short stories called "A Bright Star in the East," comments on the misery produced in a certain white lead factory in London, and expressed the hope that American ingenuity would overcome the dangers which beset the men. In one of the largest white lead works in New York City lead poisoning does not occur, owing to the ingenuity and care exercised by the management.

†The old Dutch process lead will take four and a half gallons of linseed oil to one hundred pounds of white lead ground in oil, in order to obtain a paint of maximum covering property. The new process lead will take more oil than this, and in many instances up to six gallons to the one hundred pounds of white lead paste, which contains approximately one-tenth gallon of linseed oil. On a mixed paint basis, sixty pounds of dry white lead will take forty pounds of linseed oil to produce the correct ratio, but in addition four pounds of volatile thinner, such as benzine or turpentine, can be added to increase the fluidity and assist in the obliteration of brush marks.

White lead when exposed to the elements becomes chalky after a while, and assumes a perfectly flat appearance which resembles whitewash and comes off very readily when rubbed. As long as there was no remedy for this, there was no comment on the subject, but at the present time investigators have improved paint mixtures so that this defect is not so palpable as it was in former years.*

One of the defects mentioned by many writers on white lead is its susceptibility to sulphur gases. In nature these sulphur gases are generated in two places—namely, in the kitchen of

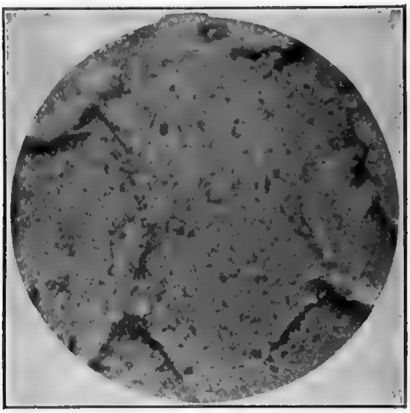

FIG. 223.—FORMULA 37, ATLANTIC CITY TEST FENCE; PURE CORRODED WHITE LEAD AFTER FIFTEEN MONTHS.

(Taken, by permission, from the Special *Bulletin* for Engineers, et al., of the Scientific Section of the Paint Manufacturers' Association of the U. S.)

every house, and in and around stables and out-houses. In kitchens, the cooking of vegetables liberates hydrogen sulphide to a great extent, the odor of which is familiar to everybody

*From many experiments made by the author, the causes of the chalking of white lead may be summarized as follows:

First. The action of the carbonic acid in rain water. If white lead be treated with water containing carbonic acid, it is found that the same solvent action takes place upon carbonate of lead as takes place upon calcium carbonate.

Second. The action of sodium chloride (salt in air). If white lead be treated with a sodium or ammonium chloride solution, a solvent action is apparent, and as sodium chloride is always present in the air at the seashore, and carbonic acid is everywhere present in the atmosphere and is readily taken up in a rainstorm, the chalking of white lead can be attributed to these causes.

Third. The catalytic action of white lead itself in being a progressive oxidizer of linseed oil. This is, however, problematical and cannot at this writing be stated with any degree of positiveness. It is quite true that white lead and linseed oil do not attack each other so readily on an interior wall as they do on a wall exposed to the elements.

who comes into a house where either cauliflower or cabbage is being cooked. But, inasmuch as undiluted white lead is not often used for interior painting, the defect is not so noticeable. A few stables or out-houses are painted pure white, and when they are painted white the painter generally has sufficient knowledge of the subject to use zinc oxide instead of white lead. It cannot be denied that the ease of application of white lead, as well as its enormous hiding power, has had much to do with the preference for it as a paint. With the exception of lithopone, it has a greater hiding property, volumetrically considered, than any other

FIG. 224.—FORMULA 38, ATLANTIC CITY TEST FENCE; PURE CORRODED WHITE LEAD AFTER FIFTEEN MONTHS.

(Taken, by permission, from the Special *Bulletin* for Engineers, et al., of the Scientific Section of the Paint Manufacturers' Association of the U. S.)

white pigment; on the other hand, gravimetrically considered, it has less body than many of the lighter paints.

The addition of an *inert filler,* such as synthetic barium suphate, silica and barytes, improves white lead considerably. These inert fillers are not affected by the usual chemical influences, and where they are used in the proper proportions, additional wearing quality or life, as the painter calls it, is given to the paint. The percentage of inert fillers which can be added to white lead varies up to 50 per cent. More artificial barium sulphate than mineral sulphate can be added. If a comparative exposure test is made, both on wood and metal, of undiluted white lead and white lead containing an inert extender, it will

be found that at the end of eighteen months the paint which contained the filler is in a better state of preservation than that which did not contain it.

*Zinc Oxide** as a paint pigment is only fifty years old, and when it is taken into consideration that in that short space of time its use has grown until in 1905 nearly seventy thousand tons were used in the paint industry in the United States, it is apparent that the material must be of exceptional merit to have advanced so rapidly. At the same time, although it is impossible to obtain any exact figures on the subject, it is probable than more than one-half of this seventy thousand tons were used in connection with other materials.

It will require a far greater proportion of linseed oil to produce the proper mixed paint than white lead will take. It is generally stated in text-books that zinc oxide is not affected by sulphur gases and therefore will not change color. This statement is not exactly correct, the author having always contended that zinc oxide is not *visibly* affected by sulphur gases, but there is no doubt, as any chemist will admit, that zinc oxide is affected by sulphur gases, although not to the same extent as white lead. As zinc sulphide, zinc sulphite and zinc sulphate are white products, the absorption is not evident to the eye, and hence the erroneous statement has crept into use that zinc oxide is not affected by sulphur gases.

When mixed with linseed oil and the proper amount of drier, it sets and dries much more slowly than white lead. Nevertheless, this drying continues in the form of progressive oxidation until the surface becomes very hard. A comparison between zinc oxide and white lead paints will show that the progressive oxidation which takes place when white lead dries, produces a chalky mixture, while the reverse is true of zinc oxide. This produces a hard and brittle vitreous surface which is somewhat affected by temperature changes. Owing, therefore, to the diverse effects of the two pigments, a combination of lead and

*The preparation of zinc oxide by Le Clair in France and Samuel T. Jones in America has been quite thoroughly written up elsewhere. The former made zinc oxide by subliming the metal; the latter made it by subliming zincite and franklinite ores. The specific gravity of zinc oxide will average 5.2, and fifty pounds will take fifty pounds of linseed oil.

zinc is often well recommended. The hard drying of zinc has not, however, been very well understood.*

When enamel paints are made of an oil varnish and zinc oxide, and the drier in the varnish is composed of manganese and lead, the enamels eventually become hard, probably through the catalytic action of the manganese. It is desirable to omit the manganese in high-grade enamels, or, where manganese must be used, in order to obtain a rapid setting, the borate of manganese should be employed, but only in very small quantities.†

Zinc oxide chalks to some extent in the same manner as white lead, but only if the atmosphere is charged with carbon dioxide or salt.‡

The zinc oxides made from western ores are slightly more permanent than those made from New Jersey ores, and as paint materials they possess the advantage of containing a larger quantity of lead sulphate. Nearly all zincs contain a small percentage of zinc suphate, which in many cases has caused unnecessary criticism.§

In the enamel paints the presence of zinc sulphate is not a detriment, and in floor paints it might be considered as a slight

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*Fifteen years ago the author undertook a series of experiments and found that the drier was very largely responsible for the hardening action of zinc. If the linseed oil is prepared with litharge (PbO), the resulting zinc paint will last far longer and be much more flexible and consequently not readily cracked when exposed to a variation of temperature even up to 130° F., such as we have in this climate. If, however, a drier is used in which manganese (MnO_2) and red lead (Pb_3O_4) have been cooked with the oil, the action of the manganese continues until a vitreous surface is the result. It is owing to the result of these investigations that the use of American zinc oxide made from franklinite ore has become so general for the manufacture of white table oilcloths. See *Journal of the Society of Chemical Industry,* Vol. XXI, No. 2, Jan. 31, 1902.

†The American zincs are:

First. The Florence Red and Green Seal zincs are made by the sublimation of the metal. These are practically pure and equal in all respects to those made in France and Belgium.

Second. The New Jersey zinc oxides, which are made from franklinite ore, and are free from lead and frequently run over 99 per cent. ZnO.

Third. Mineral Point Zinc, which is made at Mineral Point, Wisconsin, and contains from 2 to 4 per cent. of lead sulphate.

Fourth. The leaded zincs made in Missouri which contain from 4 to 10 per cent. of sulphate of lead.

‡The same experiment which was carried out with white lead in order to show its solubility in a solution of carbon dioxide, was carried out with zinc oxide, and the same result was obtained. Much weight cannot be given to these experiments, because these chemicals are not always present in the atmosphere. They are merely chemical results which demonstrate both the cause and effect, but it is of some interest to know why the paint films perish.

§Where a paint contains moisture or where water is added in a very small amount to a heavy paint in order to prevent it from settling, and not more than one per cent. of actual water is contained in the paint, zinc sulphate forms an excellent drier, particularly where it is desirable to make shades which contain lampblack. The outcry against zinc sulphate is unwarranted because as much as 5 per cent. is used in making a patent drier. The amount of zinc sulphate, however, in most of the dry zinc pigments probably decreases with age.

advantage, for it aids in drying and hardening. However, too much of the soluble salt is never to be recommended.

The ores utilized in the manufacture of *standard zinc-lead white* are what are known in mining parlance as "low grade complex ore."* The pigment carries approximately 50 per cent. pure zinc oxide and 50 per cent. lead sulphate in a mixture far more intimate than can be obtained by mechanical means. Less than twenty years ago the pigment was put upon the market. It is now made more uniform in composition, and is regarded as a valuable paint material by many mixed paint manufacturers, especially in combination leads, primers and floor paints. The color, while it is not as white as zinc oxide, is about the same shade as the average corroded white lead. The pigment generally contains a trace of silica, iron and alumina.† Photomicrographs of zinc-lead-white show an uniformity of grain and a homogeneous material. It is very stable; when exposed to the air mixed with proper proportions of linseed oil and drier, as compared with a mixture of 50 per cent. corroded white lead and 50 per cent. zinc oxide, it will be seen that the film of paint composed of zinc-lead-white is superior to that of corroded white lead, for it retains its gloss longer and does not show as much indication of chalk as the other mixture. Like white lead, it whitens on exposure, but holds up in suspension better. When a paint is made on a zinc-lead-white base ground in pure linseed oil, it will not separate, form a cake or make a sediment; neither will it peel, chalk off nor turn yellow, but care must be exercised not to add too great a quantity of reinforcing pigments.

White Sublimed Lead is an amorphous white pigment‡ pos-

*This ore contains varying percentages of zinc blende and galena. In order to furnish the product with the proper proportions of lead and zinc, the ores are first analyzed, mixed in their proper proportions and volatilized at a heat of from 2200 to 2500° F. In the volatile state it is carried to the combustion chamber, where the chemical transformation of the product, due to oxidation, completes itself. The white fume is collected in woolen bags, further oxidized on open hearth furnaces, whitened, and then bolted.

†A very small portion of the lead is in the form of a basic lead sulphate, and the pigment undoubtedly takes up a little moisture on standing. Its average analysis shows the following composition:

$PbSO_4$	50.00 per cent.
ZnO	49.55 per cent.
$ZnSO_4$	.40 per cent.

‡The author has examined a great many paints containing sublimed lead. Among one hundred reputable paint manufacturers in the United States sixty-five used sublimed lead. About eight thousand tons were used in the United States in 1905. Considering the fact that sublimed lead as a pigment is about twenty-five years old, it is very likely, judging from its qualities, that it will be used more universally and in larger quantities in the future.

sessing excellent covering and hiding power, and it is very uniform and fine in grain. Under the microscope it shows the absence of crystals. It is a direct furnace product obtained by the sublimation of galena. Within the last ten years it has come into great prominence among paint makers, it now being regarded as a stable, uniform and very valuable paint pigment.

When mixed with other pigments, such as zinc oxide or carbonate of lead, and the proper reinforcing pigments added, such as silica, clay, barium sulphate, etc., it produces a most excellent paint, and at the seashore its wearing quality is equal, if not

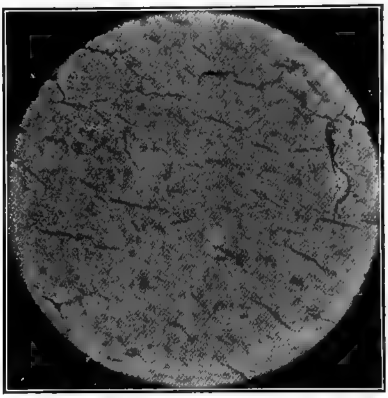

FIG. 225.—FORMULA 8, ATLANTIC CITY TEST FENCE; COMBINATION TYPE AFTER FIFTEEN MONTHS.
(Taken, by permission, from the Special *Bulletin* for Engineers, et al., of the Scientific Section of the Paint Manufacturers' Association of the U. S.)

superior, to that of carbonate of lead. In composition it is fairly uniform.*

*From the analysis of thirty-four samples of sublimed lead, its composition may be quoted as 75 per cent. lead sulphate, 20 per cent. lead oxide, and 5 per cent. zinc oxide, although each of these figures will vary slightly.

It must be borne in mind that the sulphate of lead of commerce, which is not so frequently met with nowadays as formerly, is a very poor paint material, and it must not by any means be confounded with white sublimated lead, which is at times erroneously called lead sulphate.

The lead sulphate of the paint trade is a nondescript article, which was sold as a by-product by the textile printers who used acetate of lead as a mordant, and to this liquid sulphuric acid was added and the precipitate was sold to the paint trade under the name of lead bottoms or bottom salts. Occasionally this material is still met with, and wherever it is used in a mixed paint it does more harm than good. It is likely that the pure neutral lead sulphate, which dries well and covers fairly well, could be used for ordinary light tints if diluted with the proper inert materials, but the lead sulphate which is sold by the textile printers is always acid and is sometimes coarse and crystalline, and at other times quite fine. The chemist, the paint maker and the engineer must never confound this lead sulphate with the lead sulphate contained in sublimed lead, zinc lead or leaded zincs.

White sublimed lead does not apparently react on linseed oil and therefore makes a much more durable paint compound. It has been urged that sublimed lead is not as susceptible to sulphur gases as white lead, but this the author has not been able to substantiate, for while it may take hydrogen sulphide a longer time to discolor it, it is simply a question of degree. Sublimed white lead as a marine or ship paint is of much value owing to its hardness on drying and imperviousness of film. The test fence at Atlantic City, upon which a large variety of pigments was tried, shows sublimed lead to be a very stable and very white paint.

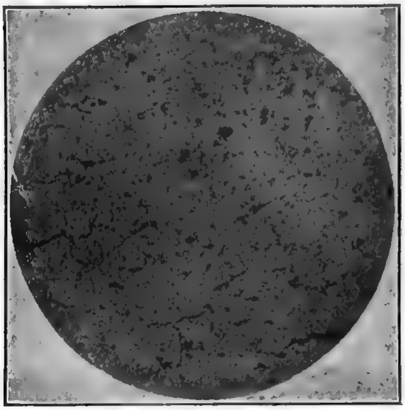

FIG. 226.—FORMULA 17, ATLANTIC CITY TEST FENCE; COMBINATION TYPE AFTER FIFTEEN MONTHS.
(Taken, by permission, from the Special *Bulletin* for Engineers, et al., of the Scientific Section of the Paint Manufacturers' Association of the U. S.)

Barytes is a white mineral having the same chemical composition as precipitated barium sulphate. In the United States Geological Survey Reports for 1904 the following statement occurs: "The value of barytes as a white pigment is being recognized more and more each year, and although very little, if any, is used alone for this purpose it is used in large quantities in combination with white lead, zinc white, or a combination of both of these white pigments. This addition is not considered an adulteration, as was the case a few years ago, for it is now appreciated that the addition of barytes makes a white pigment more permanent, less likely to be attacked by acids

and freer from discoloration than when white lead is used alone." It is also believed that barytes gives greater body to the paint and makes it more resistant to the influences of the weather. As is well known, pure white lead when remaining in the shade or in a dark place becomes discolored, turning yellowish, while mixtures of white lead and zinc white, or white lead and barytes, or white lead, zinc white and barytes, retain their color permanently even in dark places.*

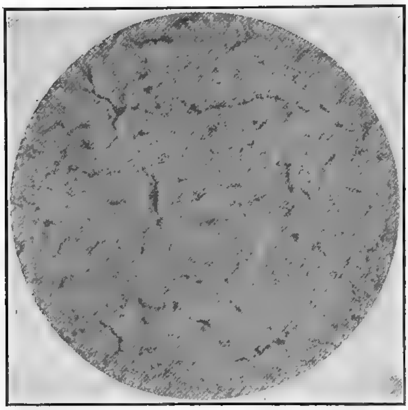

FIG. 227.—FORMULA 35, ATLANTIC CITY TEST FENCE; COMBINATION TYPE AFTER FIFTEEN MONTHS.
(Taken, by permission, from the Special *Bulletin* for Engineers, et al., of the Scientific Section of the Paint Manufacturers' Association of the U. S.)

No paint chemist will dispute the fact that barytes adds wearing quality to paint, but inasmuch as white lead has set the standard for ease of working, it is admitted that all the other pigments and fillers are not as unctuous as white lead. Therefore, the house painter will notice that the so-called lead combination which contains large quantities of barytes does not work as freely under the brush as white lead. Nevertheless, this objection does not hold good when the barytes is used in moderate quantities, that is, not to exceed one-third of the total

*The amount of barytes that can be mixed with colored pigments without injuring them is remarkably large. There are hundreds of brands of para-red paints made and consumed every year by the agricultural implement trade which contain as high as 90 per cent. of natural barytes. When it is taken into consideration that these extremely diluted para-reds cover well and serve their purpose most admirably, the expert should be very careful not to condemn barytes when used in large quantities, for this remarkable behavior is repeated with a large number of other pigments,

pigment of a paint.* The paint manufacturer is justified from experiments in recommending to his customers the use of an inert filler in his paint on the ground of increased longevity.†

A so-called "artificial" barium sulphate‡ possesses a chemical composition similar to the natural barytes, but in its physical properties it is totally different. In the paint industry it was recognized that precipitated barium sulphate was a valuable adjunct in the manufacture of paint owing to the fineness of the grain and other physical characteristics of the material. It was found, however, that when it was dried and powdered it had lost its extreme fineness and did not mix readily with oil paints. This was overcome in using it as a basis upon which to precipitate lakes.§

Lithopone¶ is made when solutions of zinc sulphate and barium sulphide are mixed together in molecular proportions; a heavy flocculent precipitate is formed according to the following reaction: $ZnSO_4+Aq+BaS+Aq=ZnS+BaSO_4+Aq$. This

*An experiment was made with a mixture of one-third carbonate of lead, one-third zinc oxide, and one-third barytes on an exposed wall of a high building in New York City, in 1885. This surface is still in a moderately good state of preservation, and as a comparison a wall painted five years ago with the pure Dutch process white lead shows that the Dutch process white lead has not stood as well in five years as the combination mixture has stood for twenty years. It is conceded that no paint is supposed to last twenty years, but as a matter of record it is interesting to note that the inert filler added much to the life of the paint which contained it.

†One hundred pounds of barytes will yield two and three-quarter gallons of paint. Owing to its crystalline structure and specific gravity, it is a more expensive pigment to use than many others when sold by volume, and a paint manufacturer who uses barytes in a mixed paint, and thinks he is the financial gainer thereby, is very much mistaken, owing to the small volume which barytes occupies in a mixed paint. It is also interesting to note from an experimental standpoint that if barytes be mixed with linseed oil and turpentine in the proportion of two pounds to a gallon, it will be found that, on allowing these two pounds to settle in a glass jar where it can be observed, it occupies only four per cent. of the bulk. In spite of much that may be said in favor of barytes, it is not better than some of the forms of calcium carbonate and some of the forms of silica. As an inert extender silica has advantage over barytes; namely, that while it produces the same physical effects with equal wearing quality, its cost is lower and it produces a surface for repainting, having what is technically known as "tooth."

The chemical composition of American mineral barytes is different from that of the German. The barytes from Germany will run from 96 to 98 per cent. $BaSO_4$. The American barytes all contain larger percentages of calcium carbonate and silica. Those that contain iron are usually bleached by the sulphuric acid process.

In 1904 the amount of barytes mined in the United States was about 66,000 tons, and the amount imported, principally from Germany, was nearly 13,000 tons.

‡It should be "synthetical," as it is made by precipitating barium chloride with a solution of sodium sulphate. Its other names are *blanc fixe,* lake base and permanent white.

§Barium sulphate has been used for years as a surface coating of paper, because when properly calendered it gives a very high polish and a permanent white surface. In the early days of the paper industry various compounds of bismuth were used for coating the paper. There are still visiting cards in existence which were surface-coated by means of bismuth carbonate and bismuth subnitrate. These cards were readily affected by sulphur gases, and when it was found that precipitated barium sulphate produced an equally high glaze and the surface retained its pristine whiteness, the name "Blanc Fixe" was universally adopted for the new product.

¶Synonyms: Oleum White, Beekton White, Charlton White, Ponolith, Jersey Lily White, Orr's White. Chemical formula, $ZnS+BaSO_4$; specific gravity, 4.2.

precipitate as such has no body or covering power, and when washed and dried is totally unfit for paint purposes, but John B. Orr, of England, in 1880 discovered that when it is heated to dull redness, suddenly plunged into water, ground to a pulp state, thoroughly washed and dried, its characteristics are totally changed, and it makes a very effective and durable pigment. In the first place, it is then a brilliant white; in the second place, it is extremely fine in texture; and in the third place, it has the same tinctorial strength but more hiding power than pure zinc oxide. It is stable in every medium known for paint purposes, excepting those which are highly acid. It took several years to perfect the manufacture of lithopone, but at the present time lithopone is made with great uniformity and has valuable properties.

Lithopone has gone through many vicissitudes; no pigment has been blackguarded quite as much as this, and yet no pigment has survived its condemnation as well as this. Almost every paint manufacturer in the United States finds some excellent use for it. It has, however, one characteristic which cannot be explained at present, and that is its power to absorb light and give it out again. This occult power of zinc sulphide is called the photogenic quality. Under normal circumstances, if lithopone is mixed with any vehicle containing linseed oil or varnish and exposed to the sunlight, it turns gray very readily, and if again placed in the dark it returns to its normal white color.*

Lithopone is very largely used in the cheaper grade of enamel paints, because it does not combine with resin or semi-fossil resin varnishes, and therefore remains unaltered in the package. As an interior white, a first coat white, a ready mixed flat paint for surface, or as a pigment in the lighter shades for floor paints, lithopone cannot be excelled for its body, durability, hardness, fineness of grain, and ease of application. It does not

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*See Toch, On the Composition of Paints and Raw Materials, *Journal of the Society of Chemical Industry,* Vol. XXI.

It has always been assumed by chemists that this discoloration of lithopone was due to its reaction with lead, and that a lead sulphide was formed which accounted for the color; but investigations have shown that this is not true, for in the manufacture of floor oilcloth, where lithopone is so very largely used, a lead drier is always used and no gray color results. If the chemical properties of zinc sulphide are looked into, it will be found that it is abnormal for zinc sulphate to liberate its sulphur in the presence of any neutral salt; zinc sulphide is stable, even in the presence of organic acids. It has further been claimed that if lithopone does not turn gray it will turn yellow when used an an interior paint, but inasmuch as this is true of any white pigment containing a soluble salt, the fault cannot be imputed to the lithopone, but rather to its manufacture.

oxidize progressively, and this single feature has made it invaluable to the table oilcloth and floor oilcloth industry throughout the world. Its indiscriminate use, however, is not to be recommended, and the paint chemist should be permitted to decide when its value is the greatest. As a marine paint, either as a first coat or for making neutral paints where other whites would be necessary, it is found to outlast both zinc oxide and lead carbonate.

*Graphite** is found as a mineral almost all over the world, and it is very largely used as a paint pigment. The purer a paint pigment is as to its contents of carbon, the poorer is the paint produced. If graphite is taken with a content of 80 or 90 per cent. carbon, and mixed with linseed oil, it forms a porous, fluffy film, and the particles of graphite coagulate in the linseed oil and produce a very unsatisfactory covering. If graphite is diluted with a heavier base, its weakness then becomes its strength and a very good paint is formed.†

Pure graphite will cover from 1000 to 1600 sq. ft. to the gallon. Such a paint film is so exceedingly thin that while it looks good to the eye, in a short period decomposition more easily takes place beneath it than beneath many poorer paints. It is, therefore, essential to reduce graphite with a heavier base, and to this end it has been found that a mixture of silica and graphite produces very good results; but even this paint has the objection of having too much spreading power.‡ So China clay is often added to pigments which have a tendency to dry coarse, to give a smoother surface.

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*Synonyms: Black Lead, Stove Polish.

†Many of the characteristic chemical and physical defects of red lead are largely reduced and frequently eliminated when it is mixed in proper proportion with graphite, a high grade of graphite, when finely ground with linseed oil, acting as a lubricant and sliding under the brush.

‡Misnomers have crept into the paint trade in regard to graphite paints, such names as green graphite, red graphite, brown graphite, etc., being in use, when in reality such graphites do not exist, excepting as far as graphite has been mixed with pigments of these colors. A six-year test of a linseed oil paint made with a neutral ferric oxide, containing in its composition 75 per cent. ferric oxide and 20 per cent. silica mixed with graphite containing 85 per cent. graphite carbon has proved itself to be as good a paint as can be desired for ordinary purposes. The pigment in a paint of this kind will withstand the chemical action of gases and fumes, but the oil as a vehicle is its weakest part.

Since the electro-chemical industry has been developed, especially at Niagara Falls, graphite has been made artificially and is sold under the name of "Acheson Graphite." This graphite is to be commended as a paint material on account of its uniformity and fineness of grain, but it should not be used entirely alone as a pigment, for as such it possesses the physical defects of lightness just described. A graphite paint containing more than 60 per cent. graphite does not serve its purpose very well unless the 40 per cent. of heavy pigment added to it is a lead or a zinc compound.

A rather unfortunate defect in the graphite paints containing a large amount of graphite is the smooth and satin-like condition of the paint film, which is poorly adapted for repainting. It has often been noted that a good slow drying linseed oil paint will curl up when applied over certain graphite paints because it does not adhere to the graphite film. On the other hand, if particular forms of calcium carbonate, silica or ferric oxide are added to graphite, a surface is presented which has a "tooth" to which succeeding films adhere very well.

The question of coefficiency of expansion in paints has not been thoroughly considered, and many a good paint will fail because it is too elastic. Engineers sometimes prefer a paint which when scraped with a knife blade will curl up like ribbon. Priming coats suffer very much when they are as elastic as this, but the paint chemist can overcome these defects by the proper admixture of inert fillers and hard drying oils.

Graphite is known as a very slow drier, but this is true only when too much graphite is used in the paint. There is no reason why a graphite paint should not be made to dry sufficiently hard for repainting within twenty-four hours.

The principal *vehicles* and thinners used as binding material for pigments are linseed oil, china wood oil, fish oil, corn oil, soya bean oil, turpentine, benzine and drier. For the average purpose of paint no substitute has been found for linseed oil. It is the best medium that we have and possesses certain qualities which could not be improved upon.

Linseed oil is the oil extracted from flaxseed which dries by oxidation. In other words, it absorbs oxygen from the air and swells, increasing its volume from 10 to 20 per cent. It forms a flexible, insoluble film which resists air and light. Linseed oil should not be used in its raw state, but be mixed with a drier which is a chemical soap of manganese, lead or zinc. These soaps act as catalytic agents and hasten the drying of the linseed oil. If we were to take an average pigment and mix it with raw linseed oil, it would take from 3 to 15 days to dry, and during that time it would collect so much dust and perhaps run and sag in such a fashion that the appearance of the painted surface would be spoiled. It is for that reason, with

one or two possible exceptions, that raw linseed oil is never used alone.

China wood oil is an oil which we receive from China and Japan pressed from the Kiri nut and is also known under the name of Tung oil. It cannot be used in its raw state, for it dries flat and translucent and as such presents no wearing qualities. It therefore must be heated with a resin and with linseed oil and properly manipulated before it can be applied. It does not possess the life of linseed oil, but for certain technical purposes, like painting dark and moist surfaces, no satisfactory substitute has been found excepting soya bean oil.

Fish oil has its uses, when boiled with a metallic oxide, as a heat resisting paint. Linseed oil when applied to a hot smokestack, for instance, does not remain in place any length of time.

Corn oil has some uses for making paste paints, which should not grow hard and stony when placed away for years.

Turpentine and *benzine* are useful as diluents where a paint is too fatty or too rich and where an even flow is desired.

Driers for linseed oil paints can be properly divided into two classes: first, resin driers; second, oil driers.

There are probably a hundred or more varieties of each of these two classes, but, carefully considered, these varieties can be sifted down as belonging to either one of the two just mentioned. The function of a drier in an oil paint is to absorb oxygen rapidly and convert the film into a hard insoluble product; and if the function of the drier would cease when the film is dry, a linseed oil plant would last much longer than it does at present.

Unfortunately all the driers to a greater or less degree continue their action of oxidation so that the paint is eventually destroyed. When we add a drying material to a linseed oil paint, the action of natural forces is hastened and the decorative effect is conserved. If we took a pigment and mixed it with raw linseed oil and applied it to a surface, it would take so long to dry that the dust and dirt of the atmosphere would collect on the freshly painted surface, and when the paint eventually did dry it would present an unsightly surface. We therefore have to add a drying material as being the lesser of two evils, although the driers are in themselves destroyers of paint. That all driers

act catalytically, some to a small extent and others entirely, is now generally admitted.

Briefly described, oil driers are all composed of linseed oil heated to between five and six hundred degrees with some salt of lead and manganese until the product thickens. Then it is reduced with benzine or turpentine or a mixture of both. This class of driers is known as "oil driers," and by themselves, when spread out in a thin film on glass, remain tacky for a long time. The other form of driers, known as the "japan driers," are

FIG. 228.—ATLANTIC CITY STEEL TEST PANELS.
(Courtesy of the Scientific Section of the Paint Manufacturers' Association of the U. S.)

metallic salts, or bases, fused with resin, or resin and linseed oil, and reduced with benzine or turpentine. When these japan driers are spread on glass they dry like a varnish in a short time. Of the two classes of driers, the "oil driers" are the better, their progressive oxidation being slower than that of japan driers.*

*The paint manufacturer should have some knowledge of the manufacture of driers, for it can be cited as a distinct example that in the making of red lead paints containing a varying proportion of red lead, a japan drier will form an additional compound with red lead and produce a livery, spongy paint, which unless quickly used becomes totally unfit for use, whereas the diluted oil driers, being thoroughly satiated, form no compound with the lead bases, and keep red lead in a normal condition longer. It has been argued that the resinates of lead and manganese when properly made should not saponify a red lead paint, but this argument does not hold good, for a resinate of lime, lead or manganese drier has additional affinity for a lead base, which cannot be said of the oil drier.

CHAPTER XXVIII.

Corrosion of Iron and Steel.

MAXIMILIAN TOCH, F.C.S.,

Chairman, New York Section, Society of Chemical Industry, New York City

It may truly be said that rust is the nightmare of the engineer, for upon the durability of steel the life of our bridges and skyscrapers will depend; nor is this fear without just foundation. There are dozens of instances where the steel in certain buildings and structures has begun to show marked corrosion. This is true, not only in the very foundation beams of buildings, which are called grillages, but in the extreme top floors with protected steels. We have also such cases to point to as the rusting out of the buckles of the Brooklyn Bridge, and the corrosion of the anchorages in the Niagara Bridge.

It has from time to time been reported that some of our large buildings are in danger of collapse. This report has little foundation, for the rusting of steel is a very slow process and manifests itself always in an observable increase in volume; for example, in the neighborhood of 220 lbs. of rust will be formed from 112 lbs. of steel. If the metal is incased in masonry, the masonry under many circumstances will burst before the factor of safety is endangered, so that, as a rule, such reports should be regarded as sensational.

In the writer's experience in matters of this kind he once observed, in one of the tall buildings in New York, that a steel beam surrounded by a masonry wall had started to rust, because it was not properly incased. The plaster on the inside of the wall being the line of least resistance, bulged and cracked, and the driving rain going through the porous wall stained the plaster. It was more or less a simple matter to correct this defect, which was done by stripping the plaster and exposing the beam, scraping the rust, applying three coats of a rust-preventing paint, and then waterproofing the wall so as to prevent a further access of moisture; for, as will become apparent later, there can be no rust in the absence of water, and if steel is properly incased in a mortar which excludes moisture, rusting cannot take place.

In December, 1908, it was the writer's privilege to examine very carefully the wreck of the battleship *Maine* in Havana Harbor. Inasmuch as that vessel was destroyed February 15, 1898, it is worthy of mention to note that a half-inch steel platform, which is shown in the illustration, had rusted through completely, so that the slight pressure of the hand served to pierce the platform and the structure crumbled under the touch.*

FIG. 229.—U. S. BATTLESHIP *MAINE,* HAVANA HARBOR. EXPOSED STEEL ABOVE WATER.

*It may be well to observe here that rust need not be the yellow form of oxide of iron with which we are familiar, and that any attempt to give an exact formula of rust would be incorrect.

In May, 1905, *Journal of the Society of Chemical Industry,* Vol. XXIV, No. 10, I had occasion to report some investigations made in the New York Subway, where rusting of the upright beams had taken place to quite an alarming extent after two years. In that communication I showed conclusively that rust may have a formula of $Fe_2O_3+2H_2O$, and $Fe_3O_4+H_2O$, or a mixture of both; the former one being the yellow rust, and the latter the dark brown variety. The analyses of iron in these various samples of rust range from 56 to 65 per cent., and the water from 6 to nearly 10 per cent. It has been the custom of writers on this subject to say that rust is the hydrated oxide of iron, having the formula of $Fe_2O_3+3H_2O$, whereas I believe it should be written $Fe_2O_3+nH_2O$.

Exposed to the air and unprotected, it took eleven years for the steel deck of a battleship to corrode completely. Of course it would have failed to serve its purpose long before if the vessel had been in commission. Properly cleaned and painted, this deck would probably be as good today as the day on which it was fabricated, for there are a number of vessels in the service of the United States Navy built at the same time as the first *Maine* which are still in perfect condition. All these facts go to prove the value of paint as a protective medium.*

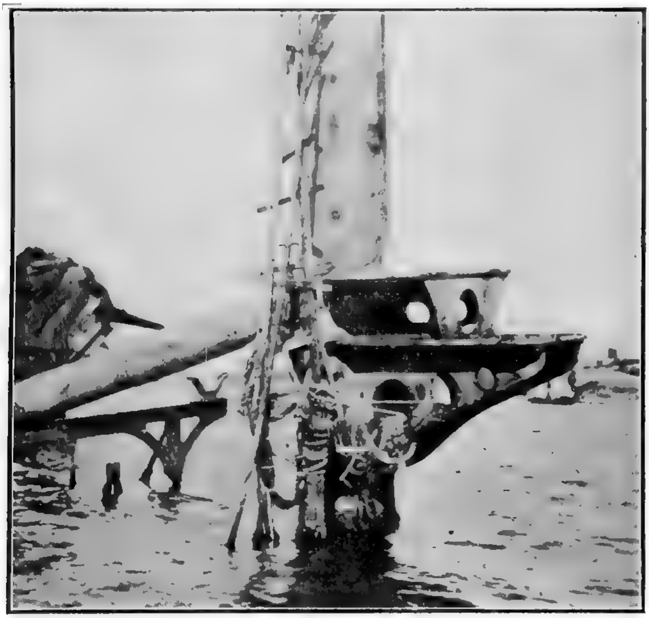

FIG. 230.—EXPOSED STEEL PLATFORM, U. S. BATTLESHIP *MAINE,* SUNK IN HAVANA HARBOR, 1898.

*A steel deck which was originally perhaps one-half an inch thick, appeared to be still intact, but on attempting to climb up on this piece of steel, it gave way under the ordinary pressure of the hand, showing that it had corroded entirely through. It was swollen very much in size, due, of course, to the molecular increase in volume. The entire amount of wreckage is a huge pile of rust with one exception. One of the masts shown in the illustration was in fairly good condition, and the paint on 75 per cent. of the surface was still intact. Films of this paint microscopically examined show that it had been extremely thick, due to no less than six or seven applications and perhaps more. Anaylses and information received from the Navy Department, indicate that this paint was a mixture of white lead, zinc oxide, ochre and Venetian red. Although this chapter does not deal primarily with the question of paint, it demonstrates quite remarkably that a mixture of lead and zinc reduced with a reinforcing pigment such as clay, silica, iron oxide, etc., is superior to any single pigment. There is no paint left anywhere on the *Maine* excepting underneath some of the wreckage where a few spots of white are still intact. This mast is in such excellent condition that a description of the paint is in place.

There are many metals which do not corrode and several metals which corrode slightly. In some instances the corroded surface forms a barrier against future oxidation. Among the metals which do not corrode are gold, platinum, silver and iridium. Among the metals which protect themselves by slight corrosion are zinc and lead. Lead, when freshly cut, shows a brilliancy equal to polished silver. In a few minutes this lustre disappears, a dull coating forms, and, as in the case of water pipes made of lead, this coating attains an appreciable thickness and prevents further oxidation. We have practically the same effect with zinc. In Flanders roofs are made of zinc and seldom painted excepting for decorative effect, as the slight coating of hydrated oxide of zinc which forms prevents any further oxidation. Iron and steel, however, are perhaps the weakest of all the metals in this respect. We have only learned within the past four years that the rusting of iron is an electro-chemical phenomenon, and having established the cause, which beyond conjecture is correct, we may have a permanent remedy. At present, however, we must consider steel and iron as exceedingly unstable metals. Steel may be electro-positive and negative all within the same plate, but if it were decidedly one or the other like zinc or copper it could be used for the manufacture of elementary batteries, which up to now has been impossible. A piece of steel, on account of the impurities that it normally contains, may set up currents and counter currents within itself, and under such circumstances will show a species of selective corrosion. I have seen and have in my possession many examples where corrosion will skip certain places and attack others.

There have been a number of theories concerning the corrosion of iron and steel, and principal among these may be cited the "carbonic acid theory," the "hydrogen peroxide theory," and the "electrolytic theory." The carbonic acid theory was perhaps the one that appeared most plausible, and there is no question that carbon dioxide and moisture will produce cyclic corrosion, which has been theoretically explained as follows:*

*Treadwell and Hall: "Analytical Chemistry," 1907, Vol. I., p. 92.

"The process of rusting is a cyclical one, and three factors play an important part: (1) an acid; (2) water; (3) oxygen. The process of rusting is always started by an acid (even the weak carbonic acid suffices); the acid changes the metal to a ferrous salt with evolution of hydrogen:

$$2Fe + 2H_2CO_3 = 2FeCO_3 + 2H_2.$$

"Water and oxygen now act upon the ferrous salt, causing the iron in this salt to separate out as ferric hydroxide, setting free the same amount of acid which was used in forming the ferrous salt:

$$2FeCO_3 + 5H_2O + O = 2Fe(OH)_3 + 2H_2CO_3.$$

"The acid which is set free again acts upon the metal, forming more ferrous salt, which is again decomposed, forming more rust. A very small amount of acid, therefore, suffices to rust a large amount of iron. If the acid is lacking, the iron will not rust. If we desire to prevent this rusting we must neutralize the acid, *e. g.*, add milk of lime. Iron remains bright under an alkali."

According to Dammer,* the carbonic cid theory was put forward in 1852, but Whitney demonstrated the correctness of the principle experimentally in 1893. There can be no doubt that carbonic acid and water will produce cyclical corrosion; and as carbonic acid is found in the atmosphere, it may assist without being the primary cause. It is just as reasonable to conclude that any acid will produce corrosion in the presence of moisture, for, if we make the simple experiment of placing a piece of steel in weak sulphuric acid, and then expose it to purified air, we will find that corrosion will take place without any carbonic acid being present.†

The instance of gas pipe imbedded in plaster of paris‡ furnishes ample evidence of complete corrosion in which water and calcium sulphate are the direct causes.§ Cushman says in his theory of corrosion:

"It must, however, be observed that this theory, although universally applicable, often has little or no apparent relation to

*"Handbuch der Anorganischen Chemie."

†*Vide* Friend, *Proc. Chem. Soc.*, June 29, 1910.

‡*Journal American Chemical Society*, April, 1903.

§The credit for the explanation of the course of the corrosion of iron is due to the work of Allerton S. Cushman, an account of which was issued by the Department of Agriculture, July 23, 1907, to which the reader is referred for further details.

the cause, for it is possible for us to corrode iron and steel in many ways. By that I mean to say, that we may rust a piece of steel by means of electrolyte, like sal-ammoniac, weak nitric acid, weak sulphuric acid, calcium sulphate, etc." All these chemical substances may be rust-producing agents just as some of the paints to which reference will be made.*

The electro-chemical explanation of the corrosion of iron is not complicated, and so far has been found in accordance with all the facts. Briefly stated, the explanation is as follows: Iron has a certain solution tension, even when the iron is chemically pure and the solvent pure water. The solution tension is modified by impurities or additional substances contained in the metal and in the solvent. The effect of even the slightest segregation in the metal, or even of unequal stresses and strains in the surface, will therefore throw the surface out of equilibrium, and the solution tension will be greater at some points than at others. From the points or nodes of maximum pressure a current will flow, provided the surface points are in contact through a conducting film. If the film is water, or in any way moist, the higher its conductivity the more rapidly iron will pass into solution in the electro-positive areas, and the faster corrosion proceeds.†

*Walker, of the Massachusetts Institute of Technology, has also done some original work on the corrosion of steel independently of Cushman, extending it by the use of an indicator which graphically shows the points of solution and the points of ionization. For this purpose, a mixture of phenolphthalein and potassium ferricyanide was utilized. Phenolphthalein shows little or no color when dissolved in alcohol and water, but turns a brilliant red in the presence of a small percentage of an alkali, and becomes colorless on the addition of an acid. Potassium ferricyanide gives the prussian blue reaction with ferrous iron. The mixture has been termed "ferroxyl" by Walker and Cushman.

When a piece of iron or steel is immersed in this reagent, the polarity of the metal during the process of corrosion is very plainly shown. At the positive pole, where the iron goes into solution, we obtain the blue coloration with the ferricyanide; while at the negative pole the phenolphthalein becomes bright red, due to the presence of the alkaline hydroxyl ions.

Walker, in his description of ferroxyl (*Journal American Chemical Society*, 1907, Vol. XXIX, p. 1257), says: "If the reagent has been properly prepared the color effects are strong and beautiful. In the course of a few days the maximum degree of beauty in the colors is obtained, after which a gradual deterioration sets in.

"In the pink zones, as would naturally be expected, the iron remains quite bright as long as the pink color persists. In the blue zones the iron passes into solution and continually oxidizes, with a resulting formation of rust. Even the purest iron develops the nodes in the ferroxyl indicator, but the impure and badly segregated metal develops the colors with greater rapidity and with bolder outlines. This result would, of course, be expected, as in pure iron the formation of poles would be conditioned by a much more delicate equilibrium than in impure iron, where variations in concentration of the dissolved impurities would stimulate the electrolytic effects."

†Positive hydrogen ions migrate to the negative areas, negative hydroxyls to the positive. By a hydrogen ion is meant a dissociated hydrogen atom carrying its equivalent static electrical charge, which may be represented by the symbol H^+. The hydroxyl ion is written OH^-. Water, which may be expressed by the symbol HOH, is made up of the dissociation products H^+ and OH^-. An acid like hydrochloric

It has been known for a long time that indentations or injuries on the water surfaces of boilers become centers of corrosion and pitting. It has been shown by Walker and others that the polarity is affected by stresses and strains on the surface, and it would seem, in view of all the facts, that this condition is determined by a number of widely different causes which might be classified as electrical, chemical and mechanical. It seems probable that the surfaces of steel which are subject to the condensation of moisture from the atmosphere are always in a state of electrical strain and polarity. The ferroxyl tests show that in a large majority of cases the positive spots once formed remain positive, and so corrosion proceeds steadily to the formation of destructive pitholes.

The methods of preserving iron and steel by means of metallic coatings are, first, the so-called galvanizing process, which depends upon dipping clean iron into melted zinc; second, doing the same with melted tin; and third, coating with lead as in the case of iron pipe which is used in chemical factories. In addition to these, steel may also be coated with an inch layer of cement mortar, as is done in building construction. Pig-

acid (HCl) dissociates into H^+ and Cl^-. An acid is always highly dissociated in solution, while water itself is only slightly dissociated. This explains why the presence of an acid increases the concentration of the hydrogen ions. Ionization always takes place in every solution of an inorganic compound, and even the purest water is slightly dissociated into its constituents, H^+ and OH^-. The more ionized a solution is, the higher its electrical conductivity, and the more rapid the damage to the underlying iron. If the concentration of the hydrogen ions is sufficiently high, which is only the same as saying if the solution is sufficiently acid, the hydrogen ions will exchange their electro-static charges with the iron, sweeping it into solution, while gaseous hydrogen may be seen escaping from the system. If, however, as is usual in ordinary rusting, the acidity is not high enough to produce this result, the hydrogen ions will polarize around the positive nodes, and the so-called electrical double layer of Helmholtz will be formed. *Weidemann's Annalen*, 1879, Vol. VII., p. 337. This polarization effect resists and slows down the action. Nevertheless, although it cannot be seen, some exchange takes place and iron slowly pushes through, as is shown by the development of the blue nodes in the ferroxyl test. For every exchange of static charge between iron and hydrogen at the positive node, a corresponding negative hydroxyl ion appears at the negative node, which is shown in pink with the ferroxyl indicator. In other words, as fast as the iron sweeps into solution the concentration of ferrous hydroxide grows, but the ferrous reaction appears in one place and the hydroxyl in another. It is now that the oxygen of the atmosphere dissolved into the solution takes up its work: The ferrous ions are oxidized to the insoluble ferric condition, which results in the precipitation of rust, and the action of hydrolysis proceeds. The formation of the insoluble ferroso-ferric carbonates and hydroxides changing to the red ferric hydroxide, known as rust, is familiar to every one. Even the purest iron obtainable shows the electrolytic nodes in the ferroxyl indicator, which proves that the equilibrium is so delicate that it is affected by the physical condition of the surfaces as well as by the chemical constitution of the metal. In a recent publication, *Transactions of the Amer. Soc. for Testing Materials*, 1908, Vol. VIII, p. 244, the writer has discussed this subject at length. It was observed that in making ferroxyl mounts, an indentation, scratch or wound of any kind on the surface of the steel invariably became positive to its surrounding area and thus formed a center of corrosion. If this had occurred only upon milled specimens which carried a coat of scale or blue oxide, the explanation would be simple, but the fact is, if a freshly polished steel mirror receives a cut before immersion, the marked place comes out in blue and corrosion takes place more rapidly.

ments, oils, varnishes and mixtures of these substances have been used, as well as enamelling with silicate fluxes. The bluing or browning of surfaces by means of forming sulphides, oxides, etc., as in the case of gun barrels, inhibits rust.

In the process of rusting, iron will pass into solution at the positive points and be rapidly oxidized to the well-known form of yellow rust with which we are familiar. Cushman says, "it is a well-known fact that colloidal ferric hydroxide will move or migrate to the negative pole if subjected to electrolysis, and that the ferric hydroxide will pile up in a crater formation while the metal is eaten out of the center. This, then, would be the explanation of the cause of pitting."

The observation is in accord with the theory that the hydrolyzing ions must reach a certain concentration which varies with different conditions.

From a personal observation, a weak solution of ammonia will cause corrosion, and a concentrated solution will act as an inhibitor. We have exactly the same condition with reference to the strong acids, for a 93 per cent. solution of sulphuric acid is usually shipped in iron or steel drums, since acid of that strength has no chemical effect on iron at ordinary temperatures. This would indicate, then, that the reverse is also true with regard to an acid in a sufficient form of concentration.

If we reduce the theory to its simple expression, it may be said that the corrosion of steel and iron resulting from exposure is ordinarily due solely to auto-electrolysis (that is, an electrical current generated in the metal itself), and therefore requires the presence of an electrolyte or solvent. Iron is soluble to a very slight extent in pure water, the negative hydrogen ions exchanging electrical charges with the positive charges carried by the iron ions. To carry the process further, the presence of uncombined oxygen is necessary to unite with the hydrolyzed iron, free the hydrogen and precipitate the iron from the solution as an oxide. Any substance which in solution tends to dissociate and increase the proportion of hydrogen ions, to that extent, stimulates corrosion in iron.

If we have bedded in the steel, not in chemical form but in the form of a mechanical mixture, a particle of manganese or

carbon, it will produce in the presence of moisture a galvanic couple in which the steel will form a negative element and the manganese or carbon the positive, and corrosion will take place more violently than it would in pure steel.*

We now come to the work that has been done with a view toward rendering steel passive; in other words, inhibiting corrosion by preventing the auto-electric condition. It has been found that certain oxidizing substances as well as certain reducing substances in contact with iron will induce a condition of passiveness during which its "solution pressure," or tendency to go into solution, is annulled, and the free hydrogen ions can no longer perform their functions in corrosion.

Of the substances found which do not tend to dissociate and ionize in solution, the soluble chromates from a theoretical standpoint have been found very effective, and if we take some pieces of steel and dip them in a solution of potassium dichromate and expose them to the air, they remain immune from corrosion sometimes for several hours and sometimes for several weeks. Attempts have been made by almost every investigator to use a soluble or partly soluble chromate mixed with paint or in the form of paint to prevent the corrosion of steel, where the paint becomes naturally abraded. Although this immunity from corrosion works out very prettily in a laboratory, so far, unfortunately, it has not proven successful on a large scale. Investigations carried out by the author in charging a piece of steel with a current of very low voltage and high amperage led to the conclusion that both the success and the failures encountered showed that the steel might become discharged of its immunizing load when brought in contact with the opposite pole, and that corrosion would then proceed.†

All these investigations by Cushman, Walker and others have thrown much light on the inhibiting action of various materials,

*Cushman: "The Corrosion of Fence Wire."

†It is merely my idea, not founded, however, on any scientific investigation, that the immunizing solution, like the chrome salts, charge the steel positively, and as long as this takes place corrosion has no effect. I found that steel treated this way and suspended by means of a rubber cord which acted as an insulator, remained free from corrosion for four weeks, but a piece of steel of the same composition allowed to lie on the table and touch a gas pipe which might ground the charge which was on it, rusted as rapidly as if it had not been placed in bichromate at all.

and fortunately we are beginning to know where we stand with reference to the various paint pigments.

The investigation to determine whether the well-known pigments used for the protection of metal in painting are rust producers, neutral, or rust inhibitors, demonstrated very clearly that certain pigments are useless as priming coats on steel and in fact dangerous under certain circumstances, and that certain others are exceedingly effective. The list of classified pigments is as follows:

Inhibitors.	Indeterminates.	Stimulators.
Zinc-Lead Chromate.	White Lead (Quick Process; Basic carbonate).	Lamp Black.
Zinc Oxide.	Sublimed Lead (Basic Sulphate).	Precipitated Barium sulphate (Blanc Fixe).
Zinc Chromate.	Sublimed Blue Lead.	Ochre.
Zinc-Barium Chromate.	Lithopone.	Bright Red Oxide.
Zinc-Lead, White.	Orange Mineral (American).	Carbon Black.
Prussian Blue.	Red Lead.	Graphite No. 2.
Chrome Green (Blue Tone).	Litharge.	Barium Sulphate (Barytes).
White Lead (Dutch Process).	Venetian Red.	Graphite No. 1.
Ultramarine Blue.	Prince's Metallic.	Chinese Blue (Stimulative Prussian).
Willow Charcoal.	Brown.	
	Calcium Carbonate (Whiting).	
	Calcium Carbonate (precipitated).	
	Calcium Sulphate.	
	China Clay.	
	Asbestine.	
	American Vermilion.	
	Medium Chrome Yellow.	

In following out these experiments, the author finds that there are a number of colors which have been omitted and a number which are inhibitors, and are commonly used and not mentioned in the original list, such as, for instance, the heavy natural oxides like the Persian Gulf red, the Lake Superior red, and certain of the hematites, which, when washed and dried, are in the same class with the inhibitors. Then again, the Venetian reds, which are made largely of calcium sulphate and which are bright reds, are stimulators, and some of the artificial oxides which have not been thoroughly washed, are likewise very poor protectors and are classed as stimulators. In every case where calcium sulphate predominates in the pigment, rusting is stimulated.

Precipitated barium sulphate may be a stimulator and may be an inhibitor. Three different samples that were examined showed three different results. The sample which showed itself to be a stimulator was slightly acid, less than 0.01 per cent. of H_2SO_4 being part of its composition. In the light of modern theory such a material would be a violent stimulator. The same sample when treated with lime-water proved itself to be an inhibitor, and when treated with barium carbonate could be classed in the indeterminates.*

In exterior painting such a condition would rarely take place, but in the painting of a subway or a tunnel of almost any kind, it is quite obvious that the vapor pressure produced by excessive moisture would show an immediate effect on steel.†

It is not disputed that graphite, carbon black, and lampblack should never be used as a priming coat. The author held this view long before the theory of the stimulative pigments was suggested, not because these materials are stimulative, but because they produce such excessively thin films and cover such a tremendous area in painting that they afford little or no protection against the atmosphere or the abrasive influence of a driving rain storm. If 231 cubic inches of paint will cover 1,200 square feet, and in some instances 1,600 square feet of surface, the resulting film is so excessively thin that there is no mechanical protection. Then again, a freshly painted film of linseed oil paint up to three months after it is applied is more or less subject to hydrolysis, and the three-week test is open to criticism on the ground that linseed oil paint of any kind is weakest when it is first applied and weakest as it perishes, and in between the

*The test which was afterwards carried out by mixing these pigments with raw linseed oil and a small percentage of drier, then painting them on a sheet of steel and keeping this steel in a moist atmosphere for three weeks, showed that some of the pigments etched the steel and some prevented corrosion, showing no effect whatever on the surface of the metal.

†This was borne out absolutely in the case of the New York Subway, where corrosion had its bad effect upon all the steel, and yet red lead was used as a priming coat which has been placed in the indeterminate class, but which will not prevent progressive corrosion under continued vapor pressure. When the Philadelphia Subway was built, the engineer in charge took advantage of the defect in the New York Subway, and used no linseed oil paint whatever, but such paints as dried in the presence of moisture and became impervious to the action of water within twenty-four hours after they were applied. In view of the fact that you cannot produce corrosion without the presence of moisture, an excluder of moisture is the proper priming material to use, irrespective of whether this excluder contains any pigment or not.

two forms a curve which, at the parabola, shows an enormous amount of protection.*

We have learned much from the work of Cushman and his associates, together with all the other investigators on this subject, and the theories that have been propounded are evidently correct, for more light has been thrown upon the subject of the prevention of corrosion within the last fifteen years than has ever been done prior to that time.

No one paint will answer all the purposes. We may have proven that carbon black and its homologues are stimulators, yet carbon black mixed with the proper reinforcing pigments will withstand the action of sunlight and abrasive storms far better than white lead, zinc oxide, prussian blue, ultramarine blue, and the entire list of inhibitors.†

*This can be easily demonstrated if we take a mixture of linseed oil, graphite and zinc oxide. Such a film will show itself to be pervious up to six months after its application. After that time, there will be a slight formation of a compound between the linseed oil and the zinc, which forms a most waterproofing coating and encysts the graphite completely.

White lead, which is an inhibitor, at the end of a year, on the contrary attacks the linoxyn film and chalks, and consequently what may be an inhibitor in the start becomes an accelerator in the end. These tests can be carried out with a mixture of pigments at great length, and reference must be made to red lead, which is unjustly condemned by many for obvious reasons. Red lead, which must dry in a damp place, generally shows up poor results, but after it has once dried it forms a compound with the linseed oil, becomes impervious to water and answers the purpose very well. A paint containing cement, in which the drier and part of the oil are made of China wood oil, will generally dry as well in a moist atmosphere as it will in a dry atmosphere, and on account of the liberation of the small amount of lime will act as an inhibitor in the very start, even though the film itself be pervious.

†The American Society for Testing Materials, in its report dated January 14, 1910, Committee "U," gives the following information with regard to the practical tests at Atlantic City:

The Atlantic City Steel Test Fence was inspected by H. A. Gardner and George Butler on January 9, 1910. The panels were divided into four groups: those showing inhibition of corrosion and good protection of the surface were termed "A;" the term "B" was given to those panels showing up fairly well; the term "C" was given to those panels which were not showing up in very good condition, while the term "D" was used to designate those panels which had entirely failed. The term "AA" or the term "DD" denotes unusual merit in the former case or unusual failure in the latter case. No detailed report, however, was made.

Old Dutch Process White Lead.
Condition A. Slightly dark.
Quick Process White Lead.
Condition A. Somewhat whiter than Old Dutch Process.
Sublimed White Lead.
Condition A. Excessive chalking present. Very white.
Sublimed Blue Lead.
Condition A. Color faded slightly to white. May be due to formation of carbonate of lead.
Zinc Lead.
Condition A. Very dark, but good firm surface.
Red Lead.
Condition A. Good hard surface.
Orange Mineral.
Condition A. Good hard surface. Slight whitening on both red lead and orange mineral; possibly due to formation of carbonate of lead.
American Vermilion (Basic Chromate of Lead).
Condition A.
Prussian Blue (Stimulative).
Condition A.

The Atlantic City test fence demonstrates for three years that the classification of the pigments in accordance with their inhibitive or corrosive qualities may be theoretically correct, but practically it is not yet established. Two classes of prussian blue have been introduced; one is called stimulative and the other inhibitive. As a matter of fact, there should be no such distinction, because prussian blue properly made should be practically and theoretically either one or the other, and any difference between two qualities would simply mean a difference in the manufacture or a difference in the washing. If we assume that oxide of iron is an inhibitive pigment, we have no right to assume that it is stimulative if it is improperly manufactured, because a pure oxide of iron would infer a material containing no by-product.

Zinc and Lead Chromate.
Condition A.
Inhibitive Paints Nos. 111, 222, 333 and 444.
All condition A.
Stimulative Paints Nos. 555 and 666.
Condition A.
Indian Red.
Condition B.
Venetian Red.
Condition B. Slight lateral cracks.
Prince's Metallic Brown.
Condition B. Slight, fine blisters showing.
Natural Graphite.
Condition B.
Artificial Graphite.
Condition B. Both the graphites showed extremely bad rusting wherever the surfaces have been abraded.
Carbon Black.
Condition B.
Lampblack.
Condition B. Carbon black and lampblack show most accelerated corrosion where surfaces have been abraded. The retarded oxidation of linseed oil when used with lampblack or carbon black probably accounts for the excellent condition of the film, indicating that both these materials are excellent for outer coatings.
Willow Charcoal.
Condition B.
Lead Chromate.
Condition B.
Magnetic Black Oxide.
Condition B.
Stimulative Paints Nos. 777 and 888.
Condition B. Both showing some cracking.
Ochre.
Condition C. Very bad blistering.
Zinc Oxide.
Condition C. This panel checked and split, showing rust. Lack of oil in formula partly responsible for result.
Lithopone.
Condition C. Mottled and pitted surface. Chalking very bad. Pink tinge noticed; possibly due to rust.
Silica and Asbestine.
Both condition C. These are the best of the inerts.
Barytes (Natural).
Condition D.
Barytes (Precipitated).
Condition D. The latter has failed completely to the steel, showing bad corrosion.

Theory shows that zinc oxide is an inhibitive pigment. Practice shows that it is such a hard dryer that the film cracks and allows moisture and gases to enter between the cracks and corrode the metal underneath. Lampblack and graphite are theoretically notorious corroding agents. Practically, a good graphite and a good lampblack make an impervious film which keeps out oxygen and water, and on that account they are rust preventors.*

Calcium Carbonate (Whiting).
Condition D. Entirely failed.
Calcium Carbonate (Precipitated).
Condition D. Entirely failed. The steel is nearly all exposed, very little paint remaining on the steel. The surface does not seem to be rusting very rapidly, however, and the alkaline nature of calcium carbonate may have rendered this surface slightly passive.
Calcium Sulphate.
Condition D. Entirely failed. Rust proceeding rapidly under the coating. The coating, however, is more intact than either barytes or calcium carbonate.
Ultramarine Blue.
Condition D. This formula entirely failed. Checking and chalking very bad.
Zinc Chromate.
Condition AA.
Chrome Green.
Condition AA.
Prussian Blue (Inhibitive).
Condition AA. The inhibitive prussian blue seems to be showing absolute protection of the metal, and its surface is without a doubt the smoothest and glossiest of any paint on the fence. The most remarkable condition of this paint should be studied and may open up a new field for this pigment. This suggests the action of the cyanides on linseed oil to prevent undue oxidation and for preservation.
Paint No. 2000. Prime coating zinc chromate, top coat excluder.
Paint No. 3000. Prime coating lead chromate, top coat excluder.
Paint No. 4000. Prime coating red lead, top coat excluder.
Good condition except for checking shown by outer coating. This checking is most marked, however, over the lead chromate.

The rest of the special paints were not reported except coal-tar paint, which was in condition D, in every case having entirely failed.

An examination of the steels which were uncoated and which have corroded seems to show that the ingot iron and the open hearth metals are rusting very evenly. Considerable pitting was shown on the high manganese plates.

*The test fences are not conclusive, for practical conditions have been ignored.

No dryer, as such, was used, and a paint containing no dryer is conceded to have a longer life than paint which contains a dryer and which continues to dry.

The paint was applied by a practical painter, who carefully and evenly brushed out the materials *in situ*. In practice men are given large brushes and the paint is applied very much in the manner in which the novice handles a broom over a dusty floor.

The surfaces of the fences at Atlantic City were carefully cleaned, and the paint was applied under proper weather conditions. In practice the paint is not always applied on a proper surface or under proper weather conditions, and the results may fail on account of those conditions.

Three coats were carefully applied at the Atlantic City test fences after the previous coat had dried properly, and in actual practice two coats are generally applied.

Notwithstanding the great care taken at Atlantic City, some of the best pigments which we have always regarded as excellent materials, ranging among the best, have shown dismal failures.

A test has been made at Atlantic City of whiting and barytes ground in linseed oil, when as a matter of fact these materials are never and have never been used as paint materials pure and simple, for they have no hiding power and are worthless as pigments. White sublimed lead has at the end of three years shown up to be the best of the white pigments. It is by far whiter than any of the others, and the film is in perfect condition with the exception of excessive chalking, which may be due to the proximity of the test to the seashore. Prussian blue has been regarded by many people as a fugitive color, but the writer has always maintained that properly made prussian blue is permanent to light and atmospheric influences. The tests of prussian blue at Atlantic City are in perfect condition as to light and permanence of the film.

Just at present we have only two ways in which we can protect a steel or iron structure from corrosion. The first way is by the proper application of a good paint with careful supervision and inspection of the surface and repainting whenever necessary. The second method is by enveloping the steel or iron in concrete. The latter method is not always applicable, and until we are able to purchase a steel which will not oxidize we will have to resort to either one of these two methods, the application of paint being the easier at all times.

FIG. 231.—STAND-PIPE WHICH COLLAPSED AS A RESULT OF THE CORROSION OF THE IRON, WHITE PLAINS, N. Y.
(Courtesy of the *Engineering News*.)

How long a steel structure will stand without protection before it crumbles entirely is very difficult to say.

The writer exhibits a picture of a standpipe which collapsed last year at White Plains. There was no doubt that the outside was sufficiently protected, but evidently the corrosion went on from the inside, and it may possibly have been due to the fact that corrosion went on under the paint, as usually such corrosion is progressive.

A careful and impartial investigation of the subject shows that cement beyond a doubt is a most perfect protector or in-

hibitor against corrosion and that concrete very often fails to protect, and corrosion once started in concrete may be progressive. The difference of opinion and result is due probably to the fact that although cement is a perfect protector, cement as such is never used, for all building construction is a reduced form of cement. In other words, a mixture of 1-3-5 may contain from 12 to 15 per cent. of cement, and therefore has no right to the term, but should be called *beton* or concrete. Then again, it is the custom on account of its lightness of weight to use cinder or partly burned coal in construction, and where a concrete made of this mixture is subjected to continual moisture the -ates and -ites, which are leached out, are likely to ionize, and these salts are corrosive agents of a marked character.

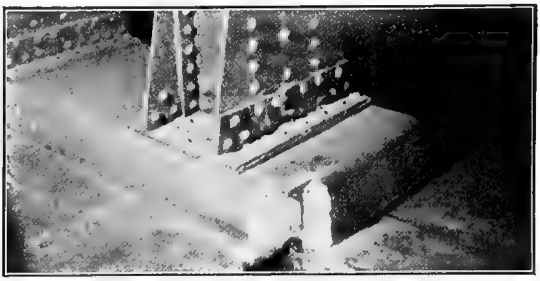

FIG. 232.—STEEL FOUNDATION BEAM PROTECTED BY PAINT COATS.

It is, therefore, wise under all circumstances to protect steel which is to be encased either with grout or concrete with a coat of paint which is alkali proof, not only to protect from the chemical corrosion which the concrete itself may produce, as in the case of cinder concrete, but for the further purpose of preventing any electrolytic action which, under certain circumstances, is likely to occur. The accompanying illustration shows the foundation beam which was coated with a cement paint as a primer and an alkali proof insulating paint as a second coat, and five years after the steel was in place it was uncovered for the purpose of investigation and found to be in excellent condition, even though the steel had not been thoroughly cleaned before it was painted. This foundation was set in concrete which was level to tide-water, and within a few hours the

excavation filled up with salt water seepage, and yet the steel did not show the slightest signs of progressive oxidation.

A well known architect and engineer in the city of New York insists in his specifications that all steel should be covered with a one-inch grout of cement before the fireproofing or other construction be placed around it. This is a very wise precaution when conducted in conjunction with an alkali proof paint, for the use of a paint which saponifies is likely to produce an air space between the grout and the steel which in the end may defeat its original purpose.

CHAPTER XXIX.

Cement and Concrete.

MAXIMILIAN TOCH, F.C.S.,

Chairman, New York Section, Society of Chemical Industry, New York City.

Finely ground materials of an alkaline nature, when mixed with water and used as a binding material for fastening stone and brick, were known in Biblical times, when it is said that the Children of Israel took clay and mixed it with straw and stubble, and used it as a cementaceous material. Even before that it is recorded that the builders of the Tower of Babel planned to "make brick and burn them,"* and it is further said that "they had brick for stone and slime had they for mortar." The Canaanite and Hebrew houses were made of crude brick, remains being found of house walls built of reddish yellow clay full of straw, and one occurrence is reported of a wall built of alternate courses of red and white bricks. The inside walls of the houses were plastered with mortar,† and the better houses used gypsum and lime. When Belshazzar saw the handwriting which foretold his doom and that of Babylon, it was upon the plaster of the wall.

The manufacture of bricks in Egypt at an early period is confirmed by numerous remains. The paintings at Thebes represent foreign captives similar to the Israelites, occupied in the same manner, overlooked by similar taskmasters and performing the very same labors as described in the Bible.‡

*Genesis xi, 3.

†Leviticus xiv, 41.

‡"Customs of the Ancient Egyptians," I, 343. In which Wilkinson, in speaking of the bricks of the early Egyptians, says:

"The use of crude brick, baked in the sun, was universal in Upper and Lower Egypt, both for public and private buildings, and the brick field gave abundant occupation to numerous laborers throughout the country. These simple materials were found to be peculiarly suited to the climate, and the ease, rapidity and cheapness with which they were made offered additional recommendations. Inclosures of gardens or granaries, sacred circuits encompassing the courts of temples, walls of fortifications and towns, dwelling houses and tombs, in short all but the temples themselves were of crude brick either with or without straw, and so great was the demand that the Egyptian government, observing the profit which would accrue to the revenue from a monopoly of them, undertook to supply the public at a moderate price, thus preventing all unauthorized persons from engaging in their manufacture, and in order to more effectually obtain their end the seal of the king or some privileged person

Bricks are found in Mesopotamia dating back to the earliest times, and from this it is believed that invaders from the east introduced them into Egypt, and that they were made in eastern countries long before the time of Moses.

We know that the Romans were familiar not only with cement mortar, but with a cementaceous material which would set under water. The inventor of the material which we today recognize as Portland cement was probably John Sneaton, who, in 1756, found a clay containing limestone, which he burned and afterwards mixed with water and sand. This formed a cement which set under water, hence was called "hydraulic." It is said that this material was used for the building of the Eddystone Lighthouse in that year. In 1796, one Joseph Parker, of England, patented a hydraulic lime which he called roman cement. He prepared it by calcining a clay containing limestone and grinding the resulting product. About 1800, Vicat, a French engineer, suggested that limestone and clay, when they were burned, formed a combination which was practically a silicate of lime. In 1824, Joseph Aspdin, a bricklayer of Leeds, patented a process for the manufacture of what he called portland cement. He proposed to make it from the dust of roads repaired with limestone, or else from limestone itself combined with clay, by burning and grinding.* A factory was built; Aspdin overcame numerous defects which his first product had possessed, and by 1850 the cement had established its value. But before this a discovery had been made in America. In 1819 the Erie canal was in process of construction. Lime had been the material decided upon and many available limestone beds near at hand had been exploited. One quarry was found, the stone from which on burning gave a lime which would not slake. This was investigated by one of the engineers, Canvass White, who had studied Parker's roman cement in England, and as a result the American Natural Cement Industry was founded.

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was stamped on the bricks at the time they were made. . . . The employment of numerous captives, who worked as slaves, enabled the government to sell the bricks at a lower price than those who had recourse solely to free labor, so that without the necessity of a prohibition they speedily became an exclusive manufacture."

Numerous brick pyramids were erected at about this time, among them one built by Asychis had the following inscription: "Compare me not with the stone pyramids, for I am as superior to them as Jove is to the other gods. Thus was I made: men probing with poles the bottom of a lake drew forth the mud which adhered to them, and formed it into bricks."

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*Meade, "Portland Cement," p. 3.

This table will facilitate a clear comprehension of what follows in this chapter.

- Simple Cementing Materials.
  - Water removed and reabsorbed—
    - Plaster of paris, flooring and hard finish plasters.
    - Cement plasters.
  - Carbon dioxide removed and reabsorbed—
    - Lime.
    - Lime-sand bricks, magnesia bricks.
- Complex Cementing Materials.
  - Oxychloride cements.
  - Silicate cements—
    - Hydraulic limes, Grappier and selenitic cements.
    - Natural cements.
    - Portland cement.

We may divide all cements most conveniently into two general classes, viz., simple cementing materials and complex cementing materials. The first contains materials which are formed by the removal of a liquid or gas and whose setting properties are due simply to the reabsorption of that gas or liquid, the set cement being thus similar in composition to the raw material from which it was derived. The second or complex class is composed of those cements in which, both in manufacture and setting, entirely new chemical compounds are formed, the set cement differing from the raw material. To the first class belong the plasters (plaster of paris) and lime mortar. To the second, the hydraulic limes, the natural and portland cements, and the oxychloride cementing materials. We may further divide our simple cements into those which are formed by the expulsion of water and whose setting is due to its reabsorption, and those in which carbon dioxide is the substance removed and restored. The complex cements are also subdivided into those in which silicates are the chemical compounds formed and those where oxychlorides are formed.

Simple Cements

The raw material from which all forms of plaster are made is the mineral gypsum. This in composition is $CaSO_4 \cdot 2H_2O$, which is known by various names according to its structure, as rock gypsum; alabaster, when in a white, fine-grained form; and selenite, when crystalline and semi-transparent. Gypsum, when heated between 212° and 400° F., loses three-fourths of its water of crystallization. In actual practice the temperature is maintained at 330° to 395° F. The resulting partly dehydrated gypsum ($CaSO_4 \cdot \frac{1}{2}H_2O$), when treated with water, combines with it, forming again calcium sulphate with two molecules of

water, or normal gypsum. Such plasters which are quick setting are spoken of generally as plaster of paris. It often happens, however, that the gypsum used contains large amounts of impurities, such as silica, alumina, iron, magnesia and limestone. These have a retarding effect on the setting of the plaster. Likewise, certain substances, usually of animal or vegetable origin, such as glue, sawdust, blood and packinghouse tankage, when added to plaster, have a similar retarding action. These slow-setting plasters are much used in structural work and are all classed as "Cement Plasters."

If, however, gypsum is heated above 400° F., all of the water is removed with the formation of anhydrous calcium sulphate, $CaSO_4$, which occurs in nature as the mineral anhydrite. It is then useless as a normal plaster. Indeed, it is usually stated that a gypsum so burned is absolutely without cementaceous value. This, however, is not so, and under certain conditions gypsum heated to a higher temperature gains valuable properties. It sets very slowly, but gives finally a very hard surface. Two kinds are made commercially: flooring plasters (estrichgips), prepared by simply burning at high temperatures; and hard finish plasters, which are produced by a double burning with the additional use of chemicals. The retention of cementing properties is contrary to expectation, as anhydrite, which is absolute calcium sulphate, possesses none. Van't Hoff has shown that "after total dehydration the capacity to bind water is at first retained and is only gradually lost either by more intense or longer heating."*

Of the hard finish plasters, Keene's cement is the most prominent representative. It is prepared by calcining a very pure gypsum at a red heat, immersing in an alum solution, again calcining, and grinding finely.

Unslaked lime is perhaps the best known of the cementing materials. In composition it is calcium oxide (CaO). By the direct addition of water, it is slaked or hydrated with the formation of calcium hydroxide [$Ca(OH)_2$]. This action, as is well known, is accompanied by the evolution of heat, but it is not to this action that the setting is due. As we have stated, in limes we are dealing with a class in which carbon dioxide is re-

*Eckel, "Cements, Limes and Plasters," p. 75.

moved from a substance and in setting is re-absorbed by it. The source of lime is limestone. Limestone in its purest form as the mineral calcite is the carbonate of calcium ($CaCO_3$). When this is heated, carbon dioxide is evolved and the oxide of lime remains. This dissociation begins at 750° C., but is usually not complete

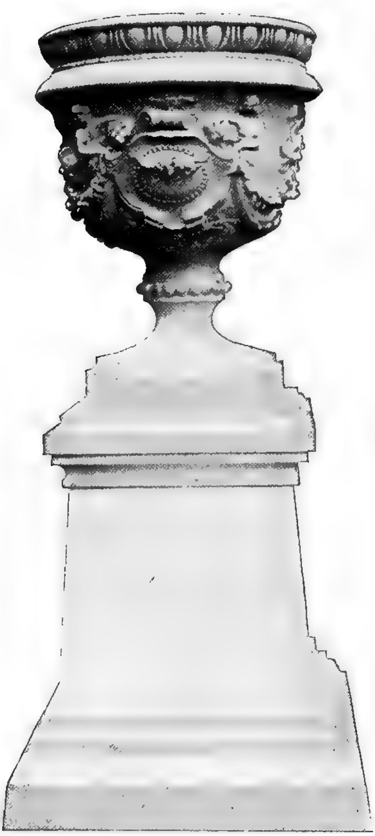

FIG. 233.—LE BLANC CEMENT AND CRUSHED WHITE CARRARA MARBLE.

until 900° C. is reached. During the burning, it loses 44 per cent. in weight, and suffers a decrease in volume of from 12 to 20 per cent.

The setting of lime can best be illustrated by that very simple experiment of our childhood days, the expiration of one's breath

through limewater. As we all remember, an insoluble, white precipitate of colcium carbonate is formed. The same thing occurs in lime. It is applied as the hydroxide in a moist state, and the carbon dioxide, of the air this time, reacts with it, producing the carbonate or limestone on the surface. The interior, however, remains unchanged.

We have said that limestone is calcium carbonate, but that is true only in its purest form. As generally found, limestone contains only two kinds of impurities: magnesia, and silica, alumina,

FIG. 234.—CASTING MADE OF WHITE CEMENT MORTAR.

iron, etc. The latter are true impurities and as such pass into the lime prepared. With the magnesia the case is different. The base magnesia, MgO, may replace the base lime. During and after the formation of the limestone, a certain percentage of magnesia is usually introduced in place of the lime, giving a more or less magnesian limestone. In such limestones, part of the calcium carbonate is replaced by magnesium carbonate, the general formula being

$$x\mathrm{CaCO_3} + y\mathrm{MgCO_3},$$

in which x may vary from 100 to 0, and y from 0 to 100. When the two carbonates are present in equimolecular proportions, the

mineral dolomite is formed. If such a limestone is burned, a lime is formed composed of a mixture of calcium oxide and magnesium oxide. Impurities such as alumina, iron, etc., remain unchanged.*

Lime alone is never used as a building material. After slaking it shrinks so much on setting that cracks develop. To overcome this, it is mixed with sand, usually three to four parts of sand to one of lime paste.

A great deal of trouble is often experienced in slaking lime, as the process is usually carried out by ignorant workmen, who, in order to be sure that enough water has been added, always use a large excess. This is, of course, better than having unslaked material present, but mortar under these conditions rarely approaches its maximum strength. To obviate this difficulty, a ready slaked lime has been put on the market under the names of "new process lime," "hydrated lime," "limeoid," etc. It does away with the waste and unsatisfactory results which are experienced with the unslaked product. In preparation, the quicklime is ground, thoroughly mixed with sufficient water and finally sifted, etc.

Lime-brick.—Bricks made by mixing gravel with a relatively small percentage of lime were made as early as 1838 in some places in New Jersey and Pennsylvania.†

Sand-brick.—There has been a recent revival of the sand-brick industry in the United States. It is of more interest to us, however, from a theoretical standpoint, as, according to some authorities, it is the connecting link between our two classes of cementing materials, the Simple and the Complex. The lime-

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*From these differences we can divide limes into two general classes (Eckel):

Group I. High calcium limes: limes containing less than 5 per cent. of magnesia. The limes of this group differ among themselves according to the amount of silica, iron, alumina, etc., that they contain. A lime containing less than 5 per cent. of such impurities is a fat or rich lime, as distinguished from the more impure lean or poor limes.

Group II. Magnesian limes: limes containing over 5 per cent. of magnesia. These limes are slower slaking and cooler than the high calcium limes of the preceding group, and they appear to make a stronger mortar. They are, however, less plastic and in consequence are disliked by workmen.

†An account of their manufacture in 1856 describes the process thus:

The common clean gravel and coarse sand of the country is mixed with one-twelfth its measure of stone lime and made into bricks. These bricks are then sun-dried and laid up into walls. . . . The moulds . . . are set on smooth ground and filled with mortar. In ten or fifteen minutes the mortar will have set so that the moulds can be taken off. The bricks are soon dry enough to handle, when they can be piled up and allowed to dry slowly. They are laid in mortar similar to that from which the bricks are made, and the outside of the buildings are rough cast with the same.—Eckel, p. 130.

sand brick hardens slowly, due, as some say, to simple re-absorption of carbon dioxide by the lime.*

Magnesia Brick.—We have also the magnesia brick, in which magnesia replaces the lime in the lime-sand brick. Magnesium carbonate, besides occurring with calcium carbonate in the mineral dolomite, is found in the pure form in the mineral magnesite. When magnesite is calcined, two different forms of magnesia, MgO, are obtained. If the calcination is carried on at a low heat, a "light magnesia" is formed which is plastic, and will absorb water and carbon dioxide from the atmosphere like quicklime, but not as rapidly. If a higher temperature is used, "heavy magnesia" results. This is devoid of plasticity and will not re-carbonate. The magnesia bricks are made of a mixture of these two forms, four to six parts of heavy to one of the light.

Complex Cements

In the present class, chemical reaction takes place with the formation of an entirely new chemical compound, by the union of two or more different substances. There are two subdivisions, in which the compound formed is respectively an oxychloride or a silicate.

Oxychloride Cements.—We will first briefly consider the oxychloride cements as by far the less important of the two. Some inert material, such as powdered marble, quartz, emery, siliceous sand, soapstone, or whatever substance forms the basis of the stone to be imitated or reproduced, is mixed with not more than 10 to 15 per cent. magnesia, and is then moistened with a solution of magnesium chloride of a density of from 15 to 30° Baumé. The bittern water of salt works is usually used. The mix is thoroughly kneaded and finally moulded. The block may be taken from the mould at once, though it does not attain

*The champions of the lime-sand brick assert, however, that, with increasing age, a certain amount of chemical action takes place between the lime and the sand with the formation of lime silicate, especially if artificial heat is used in their manufacture. The question is still an open one, but as the silicate formed in the natural and portland cements has the composition

CaO	73.59 per cent.
SiO_2	26.41 per cent.

the amount formed in a lime-sand brick containing about 8 per cent. lime can be readily seen. Eckel contends that no lime silicate can be formed below 900° C., a temperature far above that reached in the brick manufacture.

its maximum hardness for some time.* The material has been largely promoted of late as a flooring material. The cause of the cementing power is the combination of the chloride and oxide of magnesium to form magnesium oxychloride, which during the kneading is distributed over each grain of sand, or whatever substance is used, as a thin film cementing them together.

Silicate cements constitute the most important class of cements. The hydraulic properties of these complex cementing materials are due partly or entirely to the formation of tri-calcium silicate. This class includes the hydraulic limes, the natural cements and the portland cements.

The degree of hydraulicity possessed by any of these substances may be approximately calculated by a formula called originally the "hydraulic index," and which has since been modified by Eckel to the "cementation index." This index is based on the following assumptions:

(a) That the hydraulic properties of the cements are due to compounds of lime and magnesia with silica, iron and alumina formed during manufacture;

(b) That lime and silica combine to form tri-calcium silicate ($3CaO \cdot SiO_2$);

(c) That the alumina combines with the lime to form di-calcium aluminate ($2CaO \cdot Al_2O_3$);

(d) That, in their action, magnesia is molecularly equivalent to lime, and iron to alumina.

The last assumption is the only one of which we are not absolutely certain. In a great many cements, the amount of iron and magnesia is so small as to be insignificant, while in others containing appreciable quantities, a more correct idea of the hydraulic value may be obtained by considering them as we have done.

The "cementation index" is determined as follows:

$$\text{Cementation index} = \frac{(2.8+\%\ \text{silica}) + (1.1+\%\ \text{alumina}) + (.7+\%\ \text{iron})}{\text{Per cent. lime} + (1.4 + \text{magnesia})}$$

*It is claimed that the stone so formed "so closely resembles the natural stone from which the solid ingredients are obtained by crushing and grinding that it is difficult, without the application of chemical tests, to detect any difference."—Eckel, p. 163.

A theoretically perfect cement should have a cementation index of 1.

Hydraulic limes are obtained from limestone containing sufficient silica and alumina to give the lime obtained from it hydraulic or cementing properties, but which nevertheless contain enough free lime to cause the product to slake when water is added. They are of advantage in that the slaking pulverizes the cement and saves expensive grinding. Hydraulic limes have well defined limits. There must be sufficient lime present to cause the mass to be reduced to powder by its slaking, but on the other hand there must be no more free lime present than is necessary to accomplish this.*

Natural Cements.—Let us consider the cementation index once more. If it is less than one—if the lime is far in excess of the amount necessary to form calcium silicate, aluminate or ferrite—so much in excess that the calcined product slakes with water, we are dealing with an hydraulic lime. We can easily comprehend, however, that raw materials may be found in which the index is one or over, that is, in which the lime is just sufficient or not sufficient to combine with the silica, alumina and iron. Such a cement would not slake with water but would, if finely ground, set rapidly in either air or water. Such substances we have already seen were covered by Parker's patent in 1796, and are known to this day in England as roman cements. In this country they are called simply "natural cements."

A natural cement may be defined as a cement produced by burning, at a temperature usually little above that of the lime-

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*We may divide hydraulic limes into two classes:
(a) Eminently hydraulic limes whose index lies between 0.70 and 1.10.
(b) Feebly hydraulic limes whose index runs from 0.70 to 0.30.

The composition of an ideal hydraulic lime should be, according to Le Chatelier, such that the clinker should contain four equivalents of lime to one of silica. However, there is always a part of the silica which remains uncombined, so that in practice it is necessary to reduce the calculated lime content. When first made, hydraulic limes were simply calcined and then put on the market. Now it is the practice to slake the lime at the works and sift it to remove the underburned and overburned lumps. These lumps, if composed mostly of lime silicate, are finely ground and furnish an excellent cement known as Grappier cement; if composed mostly of limestone they are worthless.

Of the feebly hydraulic limes it need only be remarked that they represent the type of English limes.

A particular kind of cement related to the feebly hydraulic limes is Scott's cement or selenitic lime. This, as finally patented by Scott, consisted of the addition of 5 per cent. of ground plaster of paris to calcined hydraulic lime, which was then ground to an impalpable powder.

kiln, a clayey limestone containing 15 to 40 per cent. of silica, alumina and iron oxide without preliminary grinding, but grinding thoroughly after heating.

During the burning a number of chemical changes take place. At 100° C., water is lost; at 400° C., the magnesium carbonate begins to lose its carbon dioxide, the lime carbonate dissociating in a similar manner when 800° C. is reached; at about 900° C., the lime combines with the alumina and iron to form the aluminate and ferrite; and finally, at 1100°-1300° C., the silica and lime combine to form the silicate. Thus, if the temperature does not exceed that of the limekiln, it is probable that the cementing value is due solely to the ferrite and aluminate. Alumina and iron lower the fluxing temperature, and, conversely, as a general rule, the lower the cementation index the higher the temperature necessary to secure thorough combination.*

Portland Cements. The name "Portland" is a misnomer. When Aspdin† took out his patent, he named his product Portland from a fancied resemblance to the oölitic limestone of Portland, England, known as Portland stone. The name thus came because the cement looked like Portland stone and not because it was made in Portland. It is not, nor has it ever been, manufactured in Portland, England; Portland, Maine; or Portland, Oregon, though, as a result of the cement industry, there are a large number of post offices and towns by that name in the United States.

Refering again to our "cementation index," it will be recalled that the ideal cement is that in which the index is 1.0; that is,

*As might be supposed, the natural cements vary widely in composition. Their cementing value is usually such that their use is confined to a limited area surrounding their source, and as practically every source is different, a great many different kinds of cement are found. Eckel (p. 198) divides them into three groups on the basis of their cementation index as follows:

A. Cements with an index between 1.00 and 1.15. These products when burned at sufficiently high temperature are rather slow-setting and high in tensile strength. If not burned high enough, however, cements of such low index will necessarily contain large amounts of free lime and magnesia.

B. Cements with an index between 1.15 and 1.60. These include most American natural cements. As the index is higher than in Class A., it is not necessary to burn these products at so high a temperature. Practically all of the European roman cements will also fall in this sub-group.

C. Cements with an index exceeding 1.60. These include the relatively low limed natural cements, which carry so much clayey material that only a light burning is required in order to combine all the lime and magnesia. As the index rises above 2.00, the products become feebler in hydraulic properties.

†Aspdin's patent specified no amounts, and his original material was little better than a low limed natural cement. He gradually perfected his process, however, and laid down exact proportions.

when just sufficient silica, alumina and iron are present to combine with all the lime. We can conceive of an occurrence of clayey limestone in which this condition would be exactly met, and, indeed, in Belgium this is found to a certain degree; but since a variation of one per cent. will quite seriously effect the hydraulic properties, this condition would not often be found. Consequently, to bring it about, it is necessary to combine different substances containing the required ingredients, using such amounts that the ratio lime, silica, etc., will be molecularly equivalent. When these different substances are finely ground, mixed, heated to incipient fusion, and reground, we have a "portland cement."*

In formulating the "cementation index," it will be remembered that we assumed that the lime and silica combined to form tri-calcic silicate, and that the alumina and lime formed di-calcic aluminate. The general formula for a pure cement would then be:

$$x\ (3CaO, SiO_2) \cdot y\ (2CaO, Al_2O_3).$$

There are various impurities always present, some serving a useful purpose, as calcium sulphate, which, in small quantities, retards the setting of the cement; some are inert or harmful, as magnesia, which, at the clinkering temperature used in portland cement making, does not combine with the silica and has no hydraulic properties.

To make portland cement, we must prepare a mixture which shall contain a certain fixed proportion of lime with silica and alumina. There are various crude materials available differing in chemical composition, and also in physical characteristics, such as hardness. They may also differ in being of natural

*We can therefore define portland cement:

By a portland cement is meant the product obtained from the heating or calcining to incipient fusion of intimate mixtures, either natural or artificial, of argillaceous with calcareous substances, the calcined product to contain at least 1.7 times as much of lime by weight as of the materials which give the lime its hydraulic properties, and to be finely pulverized after said calcination, and thereafter additions or substitutions for the purpose only of regulating certain properties of technical importance to be allowable to not exceed 2 per cent. of the calcined product (Professional Papers No. 28, Corps of Engineers, U. S. A., cited by Eckel).

This definition, as set forth by the United States Army, does not require grinding before calcination. As this is generally acknowledged as necessary, the following definition adopted by the Association of German Portland Cement Manufacturers is more to the point:

Portland cement is an hydraulic cementing material with a specific gravity of not less than 3.10 in the calcined condition, and containing not less than 1.7 parts by weight of lime to each one part of silica plus iron oxide plus alumina, the material being prepared by intimately grinding the raw ingredients, calcining them to not less than clinkering temperature, and then reducing to proper fineness (Eckel).

origin, as limestone, clay, etc., or of artificial origin, as alkali waste or furnace slag.*

Even if we require that our portland cement shall have a "cementation index" of exactly one, we have not fixed its composition. We may increase the magnesia at the expense of the lime, or we may have more alumina and iron and less silica. What effect would these changes have on the cement?

The question of the ability of magnesia to replace lime in cement, giving as hydraulic a substance, is still open. Some authorities claim that if the grinding is fine enough and the clinkering temperature high enough, an entirely satisfactory cement can be made containing 10 per cent. magnesia. This theory has, however, numerous opponents, and the American Society of Testing Materials and the American Society of Civil Engineers have limited the amount to 4 per cent.

It is generally conceded that the hydraulic properties of portland cement are due largely to the tri-calcic silicate. If this is so, the ideal cement would consist of pure silicate. This is not possible to prepare in practice, as the heat necessary to bring about the combination of pure lime and silica requires the temperature produced by the oxy-hydrogen blowpipe. So, in the preparation of the cement, it is necessary to have present some impurity which will act as a flux. Alumina and iron are such impurities. If we then increase the iron and alumina, we can clinker our product at a lower temperature, but we will have a weaker cement. It is thus necessary to strike a balance between the two; we must keep the alumina as low as possible and still have a mixture that does not require too high a heat.†

The maximum amount of lime which can be allowed is, of course, an amount just sufficient to combine with the silica and alumina. In practice this theoretical amount is never taken,

*Considering only the chemical composition, there are two general methods of cement manufacture:

(a) A clayey limestone may be taken and to it added either pure limestone or clay according to whether the content of lime carbonite is less or more than 75 per cent. This is practiced in the Lehigh district.

(b) At most other plants a pure limestone is used with a slate, shale or clay. The Lehigh usage is gradually decreasing, while hard limestone and clay are being used more and more. Of the output for the year 1899, 70.9 per cent. followed the Lehigh custom, while but 9 per cent. was made from limestone and clay or shale; for the year 1908, 40.6 per cent. was made by the former and 45 per cent. by the latter.

†It may be said here that for all practical purposes the iron may be supposed to form di-calcic ferrite, similar in composition and properties to di-calcic aluminate. This has not been absolutely established, but the amount of iron present is usually so small that this supposition is permissible.

as there is always some silica which does not combine, and a shortage of lime, giving only an excess of inert silica, is better than free lime, which is harmful. The minimum amount is fixed only by the hydraulic strength desired, a low lime being a low testing cement.

Increasing the silica means decreasing the alumina, giving a cement slow setting and hard to clinker. Inversely, increase in alumina means decrease in silica, giving a quicker setting, more easily clinkered, but weaker, cement.

We assumed for convenience in the beginning that the lime and silica united in portland cement to form tri-calcic silicate, and the lime and alumina to form di-calcic aluminate, and furthermore that the hydraulic properties were largely due to the silicate. We have still to consider why this is so and how the cement sets.

For a more general definition of portland cement and to explain its setting we may say:*

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*Theories of constitution have been advanced by Le Chatelier, Newberry, and Richardson. Le Chatelier from examination of thin sections decided that the clinker was made up of tri-calcic silicate crystals imbedded in crystals of silico-alumina ferrites of lime. With lime in excess, first the aluminate, then the ferrite and finally free lime were formed. When lime was in insufficient amount, the di-calcic aluminate resulted.

The Newberrys agreed with Le Chatelier except that they held that the alumina was present as di-calcic aluminate instead of tri-calcic, as maintained by the former.

The most noted work, however, was done by Richardson. He first prepared synthetic silicates which might possibly be present in cement and carefully examined their optical properties. He made mono-, di- and tri-calcic silicates and aluminates. Then working on sections of cement clinker he identified the constituents and evolved his theory, which gives the most probable explanation. He found that the two principal constituents of a good portland cement were materials identified under the microscope by Le Chatelier and Tornebohm and named by the latter *alit* and *celit*; that *alit* consisted of a solid solution of tri-calcic aluminate in tri-calcic silicate, and *celit* of a solid solution of di-calcic aluminate in di-calcic silicate. Though the mix is never heated high enough to give complete fusion, the solid solutions are formed by diffusion, such as was shown by Roberts-Austen to take place when polished surfaces of gold and lead were brought together, the clinkering heat making this quite rapid. He cited, as another example, the rapid diffusion of a particle of ferric oxide when placed on the surface of white cement clinker and heated.

A theory to explain the setting of cement was first advanced by Le Chatelier. He ascribed the initial set to the hydration of the aluminate of lime (which he held was the tri-calcic compound) as follows:

$$3CaO \cdot Al_2O_3 + H_2O = CaO \cdot Al_2O_3 \cdot 2\tfrac{1}{2}H_2O + 2(CaO \cdot H_2O).$$

The final set was caused by decomposition of the lime silicate giving microscopic needles of hydrated mono-calcic silicate and hexagonal plates of calcium hydroxide:

$$3CaO \cdot SiO_2 + H_2O = CaO \cdot SiO_2 \cdot 2\tfrac{1}{2}H_2O + 2(CaO \cdot H_2O).$$

This theory has been modified by Richardson.

On the addition of water to a stable system made up of the solid solutions which composed portland cement, a new component is introduced which immediately results in a lack of equilibrium that is only brought about again by the liberation of free lime. This free lime, the moment that it is liberated, is in solution in water, but owing to the rapidity with which it is liberated from the aluminate, the water soon becomes supersaturated with calcium hydroxide, and the latter crystallizes out in a network of crystals which bind the particles of undecomposed portland cement together. From the characteristics of the silicates and aluminates it is evident that the latter are acted upon much more rapidly than the silicates, and it is to the

Portland cement prepared from pure materials in molecular proportions is a tri-calcic silicate mixed with an aluminate of lime in the proportion of 85 per cent. SiO_2, 3CaO and 15 per cent. Al_2O_3, 2CaO in the state of a solid solution. A portland cement may also be a solution of tri-calcic silicate with a calcium ferrite, Fe_2O_3, 2CaO. When a mixture of this nature is subjected to water, hydration takes place with the formation of a hydrated calcium silicate of lower basicity combined with an aluminate, and calcium hydrate.

Concrete.—Cement is very seldom used in its pure state. When used thus, the technical name of *"neat cement"* is em-

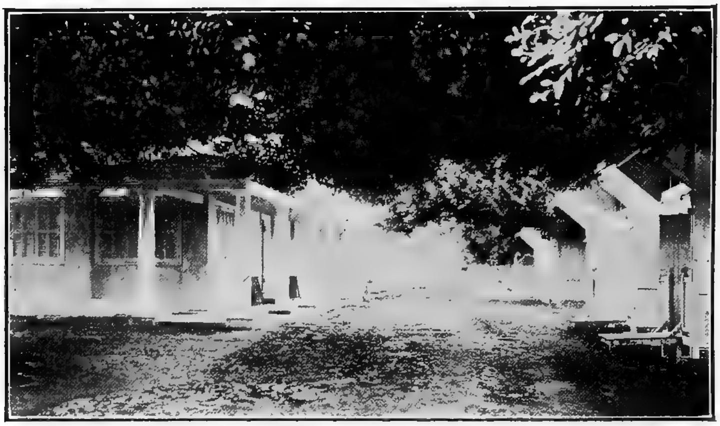


FIG. 235.—CONCRETE HOSPITALS BUILT IN CUBA OF LE BLANC CEMENT.

ployed. Better results, with possibly one or two exceptions, are obtained by mixing sand with cement, and for general construction, such as retaining walls, foundations, floors of buildings and reinforced concrete, from 12 to 18 per cent. is all that is used, the balance being broken stone and cinders. Such a mixture of cement, sand and broken stone is known under the

crystallization of the lime from the aluminate that the first or initial set must be attributed. Subsequent hardening is due to the slower liberation of lime from the silicates. If the lime is liberated more rapidly than it is possible for it to crystallize out of water, expansion ensues and the cement is not volume constant.

Of the two constituents the *alit*, or solid solution of tri-calcium salts, is the one decomposed by water (the *celit* not being acted upon), so that the high lime cements, in which the tri-calcic silicate would be present, would have greater hydraulic properties. This is as we have seen confirmed by actual experience. Richardson sums up:

The strength of portland cement after setting is due entirely to the crystallization of calcium hydrate under favorable conditions, and not at all to the hydration of the silicates or the aluminates, since in this act of hydration nothing can take place which would tend to bind these silicates and aluminates together.

name of *"concrete,"* and a mixture of cement and sand alone, when the sand is used up to 50 per cent. of the mixture, is designated *"cement mortar."* *

We can truly say that this is the cement age. In 1880, 42,000 bbls. of portland cement were made; in 1908, the production had reached 51,072,612 bbls., valued at $43,547,679. In 1880, the average cost of a barrel of cement was $3; during 1908 cement sold on the average for $0.85 a barrel.†

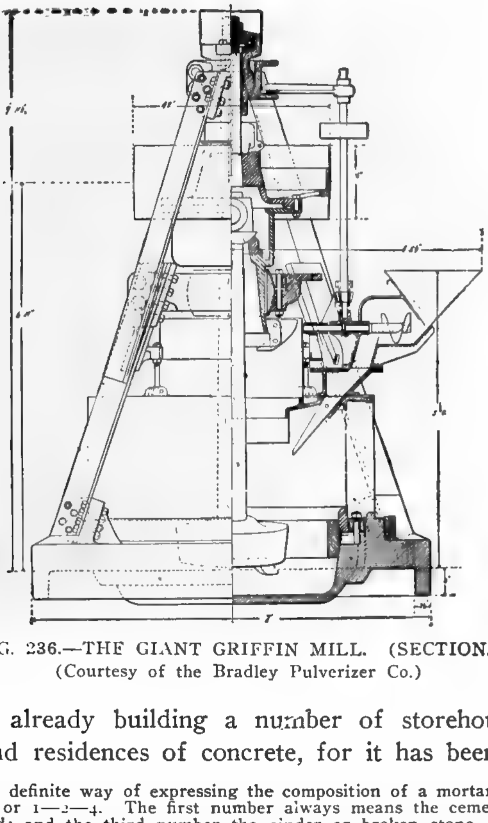


FIG. 236.—THE GIANT GRIFFIN MILL. (SECTION.)
(Courtesy of the Bradley Pulverizer Co.)

We are already building a number of storehouses, office buildings and residences of concrete, for it has been definitely

*We have a definite way of expressing the composition of a mortar or a concrete by saying 1—3, or 1—2—4. The first number always means the cement; the second number the sand; and the third number the cinder or broken stone, which is commonly called the aggregate, so that when we speak of a concrete composed of 1—2—4½, we mean one part by bulk of cement, two parts of coarse sand and 4½ parts of broken stone. It must not be inferred that the broken stone is used as an adulterant. It is used in the first place for the sake of economy and in the second place because the retaining wall or concrete structure of almost any kind is sufficiently strong when the percentage of cement ranges between 15 and 20, and it would be a waste of money to increase the most expensive material in the composition of the wall without obtaining added results.

†In addition to this, we have in this country several factories that make pure white portland cement so perfect in its composition and so uniform in the results that can be obtained that it can be used for casting statues in perfect imitation of marble.

proved that this is the most fireproof and perhaps the strongest building material of which we know. Indeed one of the arguments advanced against it is that it is too strong. It shows practically no vibration even when heavy machinery is in use.*

Reinforced Concrete.—In 1876, a French gardener named John Monier, who was constructing flower pots out of cement mortar, found that the use of a wire netting as a rig formation to hold the mortar so strengthened the resulting pots that it

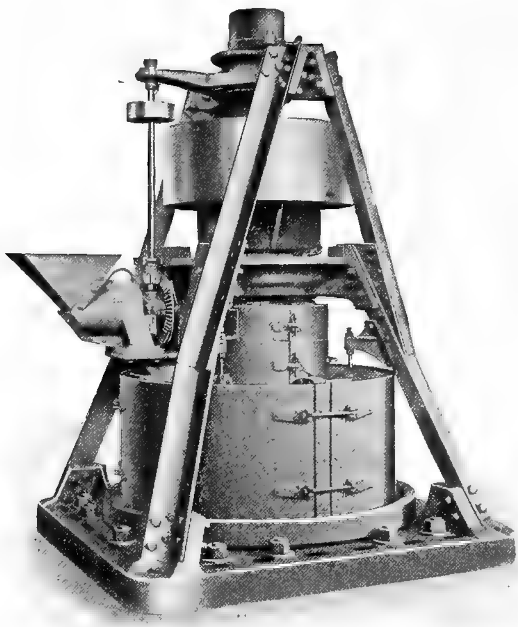


FIG. 237.—THE GRIFFIN MILL, WHICH IS USED FOR PULVERIZING CEMENT CLINKER AND OTHER REFRACTORY SUBSTANCES.
(Courtesy of the Bradley Pulverizer Co.)

was almost impossible to crush them, and from this semi-accidental use of a reinforcing material in concrete the entire industry of reinforced concrete steel has arisen. So in building a floor of concrete the first essential is to connect the beams with wire rods of varying thickness before the form is placed in position and the floor is cast. The result is almost inconceivable.

*Perry cites a case where a company had its general offices on the eighth floor of a concrete building and about in the centre a desk was placed directly over a 40 h. p. motor attached to the ceiling of the floor below. The occupant at the desk did not know of the existence of the motor.

Floor arches having a suspension of over 20 feet and a thickness of between 6 and 8 inches will carry a load of a ton to the square

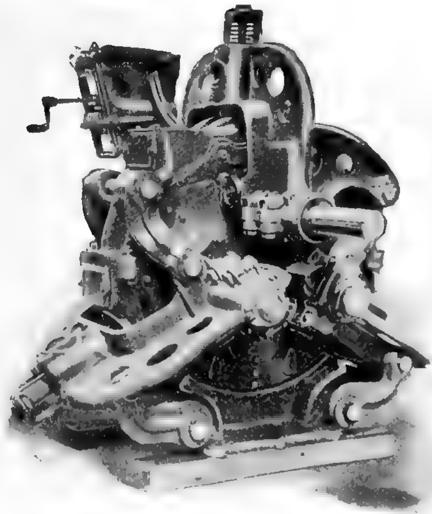


FIG. 238.—MAXECON MILL. THIS MILL IS CAPABLE OF AN OUTPUT OF 40 BBLS. OF 20 MESH-FINE CEMENT CLINKER AT A WEAR-COST OF ONE-HALF CENT PER BBL.
(Courtesy of the Kent Mill Co.)

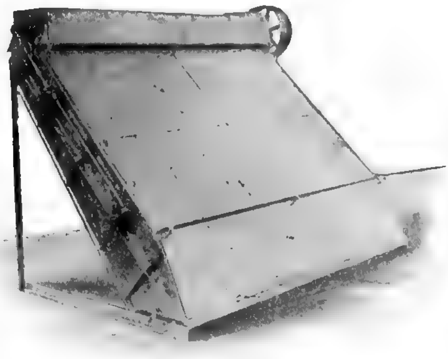


FIG. 239.—PERFECTECON SEPARATOR
(Courtesy of the Kent Mill Co.)

foot. Many engineers have advised various types of rods, as these reinforcing tension members are called.*

*The first proposed was probably the Hennebique system. Those known in this country are the Roebling, the Ransome, and Kahn systems, and many others.

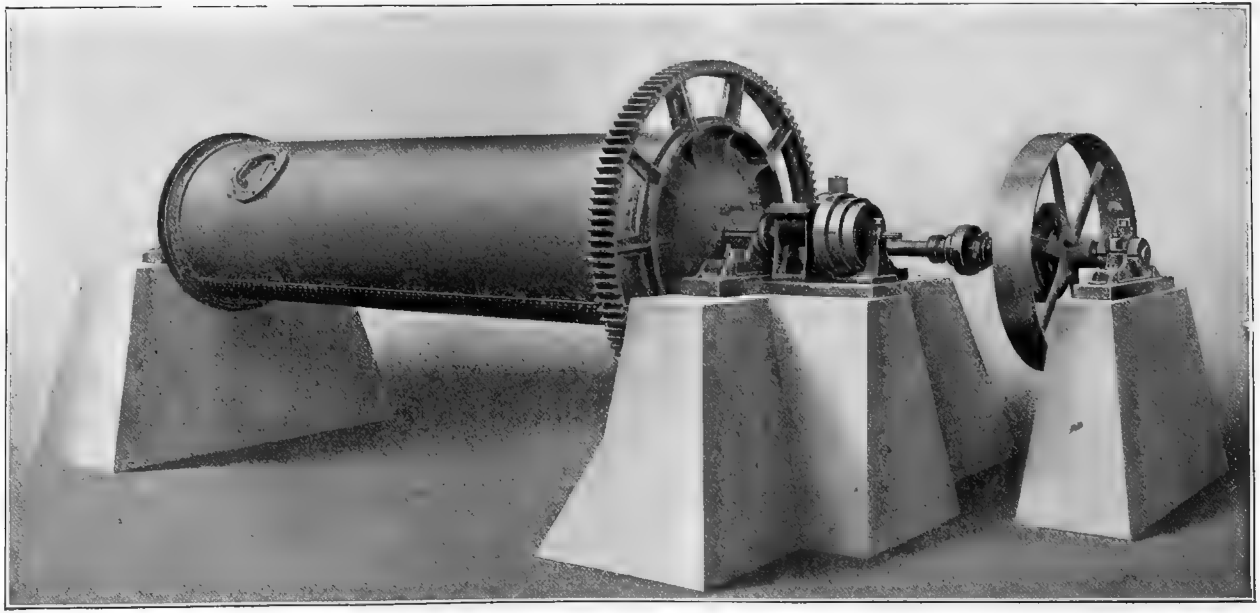
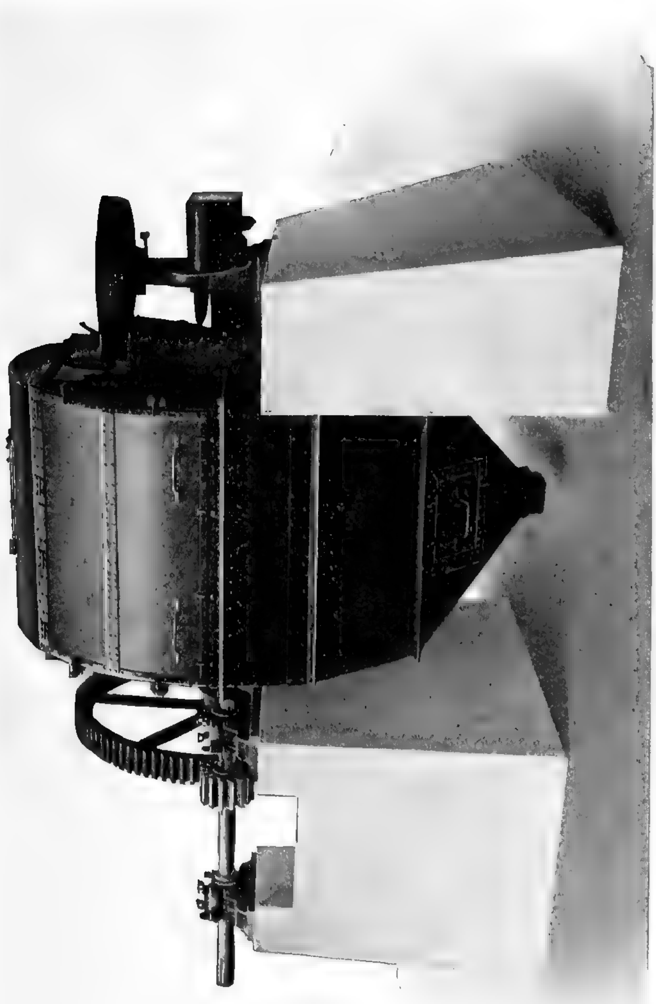


FIG. 240.—DAVIDSEN TUBEMILL.

This tubemill consists of a wrought tube mounted as a shaft by the attachment of heads so formed as to make trunnions, which rest in bearings at both ends. A large gear attached to the tube and a pinion attached to the pulley-shaft make the actuating device. The tube is lined with silex stone, and is about one-half filled with flint balls. The large grinding surface thus provided permits of a very slow speed of rotation (about 22 to 27 turns per minute, according to the size of the machine). The trunnion at the feed end is hollow, and a screw conveyor carries in the material. By regulation of the feed, any degree of fineness may be obtained.
(Courtesy of F. L. Smidth & Co.)

Concrete is now used in almost every building construction that we can think of and is always used in the reinforced type



NO. 241.—LINHARD (PATENTED) KOMINUTER.
The Kominuter is a development on the line of low speed coarse grinders. It combines, to some extent, the features of the ballmill and the tubemill, and is said to give 65 to 85 per cent. more output per horsepower than the ballmill.
(Courtesy of F. L. Smidth & Co.)

just described, with perhaps the exception of sidewalks. Where large areas of sidewalks are put down, however, reinforced members are also used.

There is one peculiar feature with reference to reinforced concrete which must be mentioned, namely, its indestructibility. It cannot be blasted for obvious reasons, and the taking down of a reinforced concrete foundation means spending days and days with a hammer and chisel, and chipping away inch by inch the hardened masonry construction.

Defects in Concrete.—Concrete has three notorious, practical defects. The first is its liability to crack in capillary fissures,

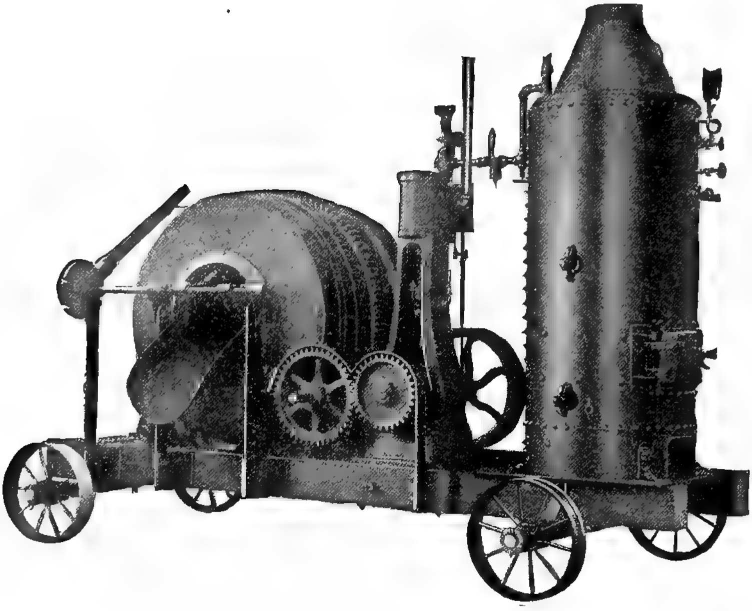


FIG. 242.—THE RANSOME MIXER.

The mixing principle of the Ransome Mixer is that of rubbing-grinding contact, a combination of rolling contact with forcible kneading. The first is accomplished through the revolution of the drum, the second through the action upon the materials of the blades or scoops attached to the drum. As the drum revolves, the material coming within the scope of one of these blades is subjected to a pressure from the sides of the trough formed by the converging blade and cylinder head. This pressure forces the mortar into the pores or crevices of the stone, and the operation is accelerated by impact.

(Courtesy of the Ransome Concrete Machinery Co.)

or in hair line cracks, the second is its permeability to water, and the third its inability to bond to old material.

The *cracking* of cement may be very largely overcome by proper reinforcement, but in the climate of North America the

microscopic cracks or hair lines are largely due to the extreme variation between summer and winter temperature. We have an example of this in the beautiful and permanent tiles which are made in Belgium, and have been used upwards of several hundred years. Since portland cement has been substituted in Flanders for the baked clays and natural cements, much more beautiful effects have been produced, and the portland cement tiles used in that country and other European countries have given perfect satisfaction. A number of concerns have attempted to make these tiles in this country 6 x 6, ⅞ inch thick, six-eighths composed of 1 to 3 and one-eighth composed of nearly neat

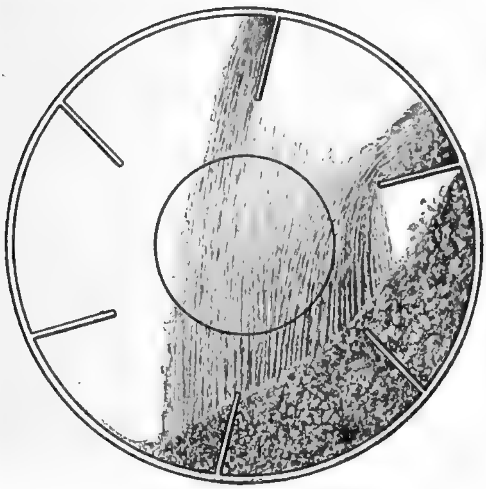


FIG. 243.—A RANSOME CONCRETE MIXER AT WORK.

cement with sufficient color for artistic effects, but no amount of judicious mixing and no amount of care was sufficient to prevent the crazing of the surface of these tiles on exposure to the elements, and even the imported tiles have not lasted more than a few seasons in this climate. It has been impossible to establish a cement tile industry in the United States for these reasons.

The *permeability of concrete to water* is a very serious problem, but it must be admitted that this permeability does not relate

to cement mortar.* If the mechanical mixing were theoretically correct, and the proper amount of water added, and the material

FIG. 244.—DISINTEGRATION OF CONCRETE THROUGH THE ACTION OF SALT WATER.

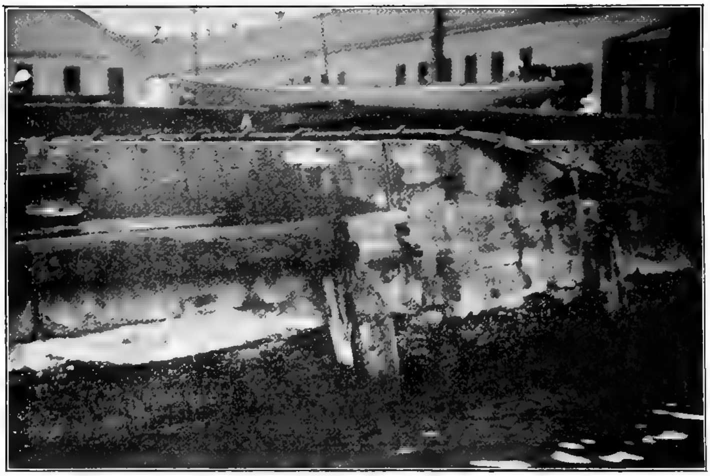


FIG. 245.—DISINTEGRATION OF CONCRETE THROUGH THE ACTION OF SALT WATER AT TIDE LEVEL.

*In building a foundation or any huge construction of cement, the mixture used is generally one part of cement, two parts of sand, and four and a half parts of broken stone. This mixture may vary according to circumstances. To one part of cement, three parts of sand and five parts or more of broken stone, the broken stone being always added for the purpose of cheapening the material, for a mixture of 1—2—4½ up to 1—3—5 or more is found to be sufficiently strong to answer the purpose for which it is intended, and the broken stone forms an aggregate which reduces the cost considerably without weakening the structure.

FIG. 246.—THE OBELISK IN CENTRAL PARK, NEW YORK CITY, BEFORE TREATMENT FOR PRESERVATION IN 1885 (PHOTOGRAPH AT THE LEFT), AND AT THE PRESENT DAY (PHOTOGRAPH AT THE RIGHT, TAKEN IN JUNE, 1910.)

These photographs show that no decay has occurred during twenty-five years. In the four years between erection and preservation, 750 pounds of stone chips fell from the obelisk; since preservation with paraffin containing creosote dissolved in turpentine (the use of creosote preventing organic growths on the surface), none at all.

(Courtesy of the Funk & Wagnalls Co.)

properly tamped into place, a uniform hard and dense material would result without any voids, but this is not the case, as has been shown time and again when reinforced concrete has been destroyed for some reason.

It is for this reason that *waterproofing materials* have been devised and invented, and there are two distinct types which appear to answer the purpose very well. The first type is the German patent by the Star-Stettin Company of the addition of

FIG. 247.—WITH AND WITHOUT TREATMENT FOR PRESERVATION.
The circles at the left were weatherproofed ten years ago and retain their original beauty. The circles at the right, left to the mercy of the climate, show marked signs of decay. This is part of a bridge in Central Park, New York City, whose carving alone cost a fortune.
(Courtesy of the Funk & Wagnalls Co.)

stearic acid to the clinker which, on setting, forms a stearate of lime, and in that manner appears to fill up the voids.*

The other type of waterproofing is that invented by the writer, in which resinate of lime is used, together with a form of silicate of alumina, which materials mix readily with con-

*This has been modified somewhat by Newberry by adding stearate of lime to the concrete in which there is a large excess of lime. The specific gravity of either the free stearic acid or the stearate of lime is such that the material is very likely to float to the top of the mixture and presents some difficulty of incorporation.

crete without floating to the top, or making any apparent waterproofing.*

The *bonding of new to old cement* is regarded as a serious problem, when, as a matter of fact, it is not serious at all. In

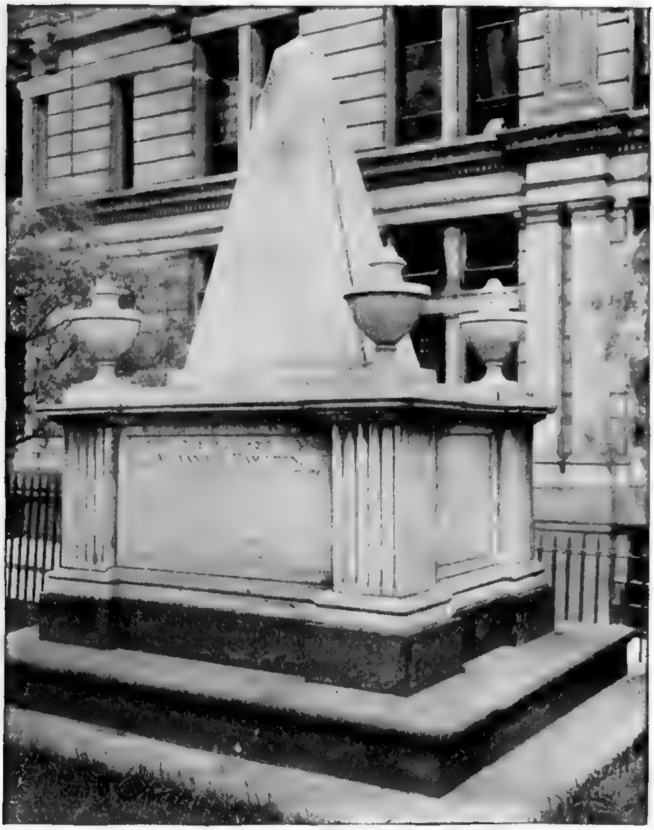


FIG. 248.—HAMILTON'S TOMB IN TRINITY CHURCHYARD, NEW YORK CITY.
The decay of the stone of this important historical monument has just been arrested by a coat of paraffin.
(Courtesy of the Funk & Wagnalls Co.)

*The silicate of alumina not being ordinary clay, but being a material which presents colloid features when it is mixed, infiltrates into the microscopic interstices of the concrete and after a lapse of three weeks appears to waterproof the concrete most thoroughly even against abnormal pressure. The writer has lately improved this material with reference to sea water concrete, which may be of value insofar that a fatty acid is employed in small quantities together with the mixture just described, and in the setting glycerine is naturally liberated. This glycerine is taken up with its proper amount of lead oxide, glyceride of lead being formed, and a mass of concrete containing 2 per cent. of such a mixture appears not only to be waterproof a few days after it has set, but becomes perfectly impervious to the action of saline solutions.

almost every construction the work shows a line of demarcation, which frequently develops a crack or fissure that may be detrimental to the work later on, but a five per cent. solution of muriatic acid applied to old work, then thoroughly broomed off and swept clean, and washed copiously with water, presents an etched surface, due to the action of the acid on the alkali of the concrete which invariably holds new to old concrete as perfectly as if all had been placed in a continuous operation.*

*It has been argued that it is difficult to transport solutions of muriatic acid to distant points, but actual practice has demonstrated that this presents no real difficulties. At the same time there are other materials that can be used in bonding, as, for instance, sulphate of soda or bisulphate, which when dissolved in water will etch the surface of concrete practically as well as a weak solution of muriatic acid.

CHAPTER XXX.

Parks, Gardens and Playgrounds.

NATHANIEL LORD BRITTON, Ph.D.,
Director of the New York Botanical Garden, Bronx Park, New York City.

Public parks, gardens and playgrounds are areas vitally necessary for the well-being of a large majority of persons resident in cities. They provide attractions and inducements for at least a certain amount of out-of-door life amid surroundings more or less approaching country conditions, partially devoid of the distracting environment of streets. The progressive concentration of population in the cities constantly increases the importance of open spaces. Their value from the standpoint of hygiene has never yet been fully grasped, although it is widely intuitively understood. For all classes of people whose occupations lie within buildings, they afford a means of relief from care, available even to the poorest, and to the poor they are a kind of philanthropy, the importance of which can scarcely be thoroughly appreciated by the rich without personal observation of the enjoyment and benefit provided.

These are facts which have been more or less generally recognized in the planning and development of cities for a very long period of time, and provision for public grounds has been widely made.

That sufficient open space properly distributed through a city has never yet been reserved in original plans is doubtful, but some cities, taken collectively, have made considerable provision. There is no doubt that satisfactory planning of parks, gardens and playgrounds with relation to density of population is a difficult problem, because it is not always, or even often, known long in advance just in what direction the building up of a city will progress most rapidly, and this consideration calls for a liberal allotment of space, so that there shall be sufficient in any event. If this is not done, it becomes increasingly difficult to provide public grounds, owing to their progressive increase in value and the large public expenditures thus entailed

for securing them. It is a significant fact, however, that in scarcely any instance has criticism been made after the beneficial effects of such expenditures have been demonstrated, and

FIG. 249.—INTERIOR OF A TROPICAL HOUSE, NEW YORK BOTANICAL GARDEN.

all propositions contemplating any diminution of park areas are met by pronounced public disapprobation.

Parks, in the American sense, and playgrounds, also in the American sense, cannot be satisfactorily maintained on identical

areas. In our development of public city grounds, the park is devoted to rest and recreation, and embellished so as to be as æsthetically attractive as possible, in this respect approaching

FIG. 250.—GIRLS' DAY, PELHAM BAY PARK, NEW YORK CITY.

the old world conception of gardens, and requires high expense for maintenance and for guarding. The playground is devoted to more or less violent exercise, not conducive to rest and requiring no embellishment. Small parks and parts of large parks

may well be set aside as playgrounds when required, but for the maintenance and recreational functions of the park proper, it is almost necessary that the two be sharply delimited by some barrier or other well-defined boundary; the conception of the different functions of park and playground, as developed with us, would thus be emphasized and damage to park features would be avoided.

The hygienic importance of parks and gardens lies in the relief from distraction by noises, odors and unpleasant sights, perhaps, as the most important functions; in the opportunities for

FIG. 251.—LION HOUSE, NEW YORK ZOOLOGICAL PARK.
(Courtesy of the New York Zoological Society.)

rest and recreation; and for walking on other than paved sidewalks, a consideration not always thought of, but in itself a kind of rest; in the pleasing experience of viewing natural objects and works of art, pleasing sights being certainly a kind of recreation; and in the opportunity of spending time in the open air, relatively, at least, less contaminated than that of buildings and streets, a breath of the country brought into the city.

Playgrounds are of high importance hygienically, especially for the young, as providing space for healthy, vigorous exercise under safe physical and sanitary conditions. They have, as yet,

obtained but little of the development which they are certain to receive, though much has been accomplished in many cities during the past few years.

The educational functions for which parks, gardens and playgrounds are adaptable are second only in importance to those of hygiene, and these functions are numerous and various; in this consideration the teaching of natural science and the stimulation of love for natural objects take first place.

Trees are freely used in the construction of parks and gardens as elements of the landscape design, for shade and as individual objects of beauty; they are thus brought into ready availability for informational purposes as well, and, if a considerable number of them are labeled, showing the names, the country in which they are native, and other features of general interest, they become at once objects of information; a knowledge of the commoner trees and their uses is certainly a desirable element of public instruction, and if it had earlier been made a part of school work, the campaign for the preservation and conservation of forests would much sooner have reached success.

Shrubs and herbaceous plants are also used, in variety, for landscape and decorative purposes, and are thus at hand in parks and gardens for demonstrating features of botanical nature study, and elementary horticulture and agriculture. Nearly all parts of a park will thus contain plants from which lessons may be learned while experiencing the enjoyment and vital stimulation of being out of doors.

Animals, also, are inhabitants of parks and gardens, not alone the cared for collections in zoological parks and menageries, but many wild ones as well, and are available as objects for demonstrating nature study and elementary zoology. Some acquaintance with the larger wild animals—at least, birds and mammals, their habits and uses and the necessity for their preservation—is of distinct educational importance.

The rocks, stones, soil and bodies of water of the parks are natural objects which may aid in the teaching of elementary geology, mineralogy and chemistry. The open spaces afford opportunity for observing the stars and other celestial bodies and for instruction in elementary astronomy.

Playgrounds may, and should be, developed into important educational factors for instruction in gymnastics and athletics; properly directed exercise by play leaders and otherwise is much needed in the cities, and the present movement to increase and elaborate this instruction is worthy of all encouragement.

School gardens, in which children are taught how to cultivate vegetables and flowers, are now a recognized feature of educational work in many cities, but in most instances the land for such purpose is not owned by the municipality. School gardens might well be made a permanent part of the park or educational system of every city, either in connection with school grounds or in convenient locations elsewhere.

The æsthetic functions of parks and gardens as natural and artificial landscapes are other features of importance, both in respect to public recreation and public education. An appreciation of the beautiful in nature and in art is most desirable to inculcate in every community, for it adds to pleasure and stimulates civic pride. Well thought out general plans are essential for the satisfactory development of artificial landscape and for the preservation of natural features. Such plans should be based on careful preliminary surveys and should also take into account practical considerations, such as drainage, water supply, boundary walls and fences, entrances, the location of necessary buildings, and places for works of art; paths and driveways should be so located as to readily affect the distribution of crowds and lead easily from one feature to another. It is not possible to foresee all the details desirable, and plans should therefore have a certain amount of elasticity, allowing for contingencies which may arise as the work of development and embellishment proceeds.

Unfortunately a small proportion of every community fails to appreciate beauty in parks and requires much education, sometimes of a strenuous character, these people being naturally and even wilfully destructive. Guarding and policing are necessary for the protection of park and garden features, and entail an expense which is to be regretted, but which is unavoidable. In this connection it may be said that the policeman who watches for the criminal only is not the desirable officer for park service. He should be more of an informational guide, who appreciates the trees and the flowers, and by his influence spreads the feel-

ing of reverence and affection for the beauties of nature rather than awe and fear of the station house.

Institutions of art and science, such as art galleries and museums, natural history museums, observatories, botanical and zoological gardens, have been appropriately located in parks in many cities and are highly important factors in public education and recreation.

The maintenance of parks and gardens depends upon the upkeep of the soil. Forest areas annually renew their soil by the decay of fallen leaves and twigs, but in other parts of parks and gardens plants are continually abstracting food from the soil and replacing little or nothing, for weeds must be removed, lawns must be mowed and leaves raked up. Chemical examination of the composition of the soil is therefore desirable from time to time, as furnishing information as to its needs. The combating of insect pests and destructive parasitic fungi by spraying trees and other plants with poisonous solutions is necessary.

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